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PHYSICAL SCIENCES AND TECHNOLOGY
(FOUO 10/79)

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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

DESCRIPTION OF ASU's 'KUNTSEVO,' 'L'VOV,' 'SIRENA-1' AND 'PRIBOR'

Moscow OSNOVY POSTROYENIYA AVTOMATIZIROVANNYKH SISTEM UPRAVLENIYA in Russian 1977 signed to press 16 Sep 77 pp 279-288

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[Text] 8.1. The ASUP "Kuntsevo"

The "Kuntsevo" system was developed by the Moscow radio equipment plant jointly with the Institute of Cybernetics of the USSR Academy of Sciences as a typical automated management system for enterprises with discrete production [37] (which include a large portion of industrial enterprises, for example, the instrument-making or machine-building sectors of industry). The system is intended for enterprises with mass, large-series or small-series production.

The development of functional subsystems for the technical preparation of production, the scheduling of production, the supplying of production with materials, technical-economic planning and bookkeeping are among the former.

The organization of effective functioning of the ASUP "Kuntsevo" is based on the following servicing subsystems: informational servicing [49], technical servicing [60], software [50] and organizational servicing [37].

In the ASUP "Kuntseva" provision is made for the development of the necessary program and organizational means of construction of information-reference and information retrieval systems. The latter are intended mainly for retrieval of design technological information. In the information-reference system a language is used in which questions and answers are formulated, one similar to that ordinarily used by the production specialists. In addition, a system has been adopted for information coding by means of coding guides that have considerable advantages over classification systems because of ease of recall and simplicity of mastering. The information-reference system is intended for gradual transition to control from regulated presentation to plant control services of data in a previously standardized form to obtain any kind of information (with any depth and in any profile) in the process of development and adoption of decisions.

Used in solving problems of optimum planning and control are methods of modeling production with different degrees of detail and on different levels, and also methods of forecasting production and evaluating the alternative planning solutions. Envisaged in the software is the possibility of solving proglems of mathematical programing, mathematical statistics, queuing theory and linear algebra.

There is a possibility of continuous modification and planning of plan tasks for production sections, shops, procurement services and the material and equipment supply section. Included in shift tasks are lists of produced parts, of operations completed, with an indication of the time required for their execution, of the equipment used to perform the operations and of the workers engaged in the performance of those operations.

Deviations of production from the schedule and forecasts of possible violations of production plans, with an indication of their causes, are regularly reported to the production control services at the enterprise.

On the basis of methods of decomposition (solution of a system of linear equations) provision is made for the solution of problems in the preparation of summary design documentation with respect to local solutions and improvements. It is interesting that in the process of preparing documentation for new production the documentation on solutions borrowed from other production can be prepared without the participation of man. Provisions are being made to develop by means of computers a technology for individual types of technological operations.

Data processing is entrusted mainly to the enterprises, where all the accounting and standards data are concentrated. Through the IVTs all the documentation of an economic-planning and technological-design type is being done; it bears responsibility for providing all services with reliable, timely and complete information.

The worker obtains from the IVTs shift tasks with the foreman's signature and also summary data on the indicators of his work. Into the IVTs from the worker come reports (with the approval of the department of technical control) on the results of execution of the technological operations and work. Simultaneously with the increase or receipt of naterial values the warehouseman reports to the IVTs that the operation has been completed. The card file on the presence, arrival and expenditure is kept in the IVTs, from which the necessary information on all positions on the state and dynamics of movement of stocks in the warehouse goes to the warehousemen, and the prescription for the issuance of values is formed. The foreman regularly obtains from the IVTs summary documentation reflecting the shift tasks and the summary indicators on the work of his sections, the expenditure of wages and incentives in the section; upon request he can obtain a schedule graph and work indicators for a definite period (shift, 10-day period, month, etc). The shop chief has the same possibilities with respect to data on the shop.

Calculations of wages, material expenditures, the movement of product in the process of production, costs, depreciation deductions and others are made in the IVTs. Only isolated unmechanized operations in accounting are performed by the bookkeeper. Every day (or upon request) the bookkeeper can obtain from the IVTs information about the state of the records and input-output items and also the accounting balance on the state for the date preceding the inquiry.

The personnel card file is also kept in the IVTs, and all changes regarding the workers are recorded by an electronic computer from reports of the personnel section.

The enterprise management can upon request obtain by means of the reference-information system information of interest to it regarding the state and trends in the development of production (statistical forecasts, production schedules, etc).

The economic and planning services of the enterprise calculate the plan and analytical indicators through the IVTs in the preparation of given planning solutions and analysis of the program of production, marketing and sales of output.

In the IVTs all the report information required by the higher authorities is prepared, and statistics are also kept of the fulfilment of their obligations by suppliers, users and other organizations.

Periodically at the prescribed time the IVTs of the enterprise transmits to the GVTs OASU [main computer center of the automated control system for the sector of industry] (over a communication channel or in the form of recordings on a data carrier) report data on the production and economic activity of the enterprise. At the request of the GVTs any information contained in the "automated card files" can be transmitted in systematized or unsystematized form. Data of a directive character arriving from the GVTs and IVTs are reduced to information of the enterprise management and the decisions made by management are reported to the IVTs.

The technical servicing of the ASUP "Kuntsevo" envisages a two-stage structure of the hardware complex, consisting of an IVTs and group peripherals connected to the IVTs through data transmission equipment.

The IVTs is equipped with a "Minsk-32" electronic computer, a device for coupling the computer with "Minsk-1560" communication channels and various service equipment: a KSU-50 unit for perforated tape preparation and control; RMK-80/45 and RM-80 punched card decoding machines; an REM-600 K rotary electrographic machine for the reproduction of forms issued by the computer; a UPB [ustroystvo, podayushcheye bumagu--paper feeding device] serving to form break lines on paper by punching a row of holes; a BRP-2M paper-cutting machine and a BShP-4 stapler; STVM-30 voltage stabilizers and air-conditioning installations. Parallel operation of two electronic computers is assured, with direct data exchange between the working storages, where one machine works on a real time scale and is used for the collection and processing of data arriving directly from the place of its formation and also for the solution of more urgent problems, and the second machine is loaded with non-urgent problems and provides redundancy of the first computer.

In the first ASUP line the peripheral points are equipped with production registers, T-63 roller teletypes and FTA-P2 phototelegraphic units. In the second ASUP line, RP-11, RP-51 and RP-101 production registers are installed at the peripheral points. Automatic ARP-1M production registers are also used, and electron-beam displays.

Three levels of planning were used in the ASUP "Kuntsevo":

-- the development of standard design solutions suitable for most enterprises of the branch;

-- the creation of standard designs of ASUP for basic enterprises on the basis of standard solutions of the ASUP "Kuntsevo";

-- the creation of designs for the coupling of basic ASUP.

Among the standard design solutions are standard hardware for data collection, transmission, processing and storage, stanadard methods of data processing, standard circuits and programs for the solution of problems of control, standard programs of system software, and standard organizational principles of the development and introduction of ASUP.

Standard design solutions of ASUP are being developed at eight basic enterprises. Being primarily developed are the structures of a technical complex and an information system, the functional and organizational structure, the standard structure of an operational system, standard data tables for the solution of problems and standard network modes for the development and introduction of ASUP. Expenditures on the creation of standard designs can amount to several million rubles, and the work can take 3-5 years.

Coupling designs are individual, since they take into account specific differences of a given enterprise from the basic enterprise. They determine the specific modifications of a standard plan and measures to bring close together the production and the functional, the organizational and the informational structure of a given enterprise to the corresponding structures of the basic enterprise. In that case the development times and the expenditures on planning are reduced by one-half or two-thirds.

Leading institutes on control systems for coordination of work on the creation of ASUP have been created in each branch. They have to study the level of mechanization and automation of control work, determine the basic enterprises, develop standard design solutions and lead work on the creation of standard designs of ASUP.

8.2. The ASUP "L'vov"

The ASUP "L'vov," functioning at the L'vov television plant, is intended to increase the effectiveness of production by improving operating production planning, calculation of the optimum regime of the enterprise and synchronization of the course of production through the rational distribution of available resources, and also the solution of problems of accounting, the provision of production with materials and equipment and technical-economic planning. The system includes the following subsystems [103]:

-- operating control of the main production;

-- technical-economic planning;

-- control of the supply of materials and equipment;

-- control of marketing;

-- accounting;

-- personnel management.

The following devices are a part of the hardware complex of the first line of the ASUP "L'vov":

-- two "Minsk-22" electronic computers, supplemented by a system of program interruption, memory protectors and supplemental commands;

-- device for data input from telegraph equipment into computer and output to telegraph lines of communication, assuring simultaneous operation of 30 telegraph units;

-- device for data output on luminous display;

-- current time generator for synchronization of control and accounting with the course of the production process;

-- device for coupling computer with data transmission equipment over telephone lines of communication;

-- electronic commutator working according to a prescribed program, intended for the connection of additional peripherals to the computer.

The counters of the quantity of output have normally closed contacts which are connected to the stamps of the technical control department. During the marking of finished goods the contacts of the sensor close and a signal is sent to the computer. In the sensors of the state of the equipment there are normally open contacts which are periodically closed during movement of the assembly shop conveyer and other equipment. Intermediate counting devices and controls (of the control panel) and data transmission equipment are situated at the dispatcher points of the shops. A luminous table, registering devices and some of the dispatching equipment are installed in the main dispatcher point of the plant. Devices of the type of the URI-4 are installed in the warehouses.

In the first stage of introduction of the ASUP software system a complex of programs numbering over 50,000 commands was included. In the software of the ASUP "L'vov" it is possible to distinguish programs for the solution of economic tasks and system programs [104]. The task of the automation of programing is reduced to the construction of an algorithm for the complex processing of data in the ASUP which satisfies such requirements as the systematic nature of the approach, flexibility and optimality of the solution, depending on the specific conditions.

The introduction of the first line of the ASUP "L'vov" is characterized by the following indicators:

1) the reduction of non-productive downtimes and improvement of the rhythmicity of work of the enterprise, increase of the volume of production by 6.6 percent on the same production areas and reduction of wastage;
2) improvement of the completeness of assembly and reduction of the general level of stores through the organization of daily recording at the warehouses of operating analysis of the movement of material values and control of the procurement process.

Thus, in 1.5 years of operation of the system the mean level of stocks has been reduced by 15-20%, and this permitted the release of about 300,000 rubles of "frozen" assets. In addition, the period of repayment of circulating capital was reduced by 6 percent. The annual saving was 468,000 rubles at a repayment period of the system of 2.5 years.

8.3. Automated Systems for Transport

As examples of the application of automated systems for transport we will examine a system of airplane seat reservation and a system of planning and control of motor-vehicle transport.

The automated system "Sirena-1" is intended for the servicing of airplane passengers flying from Moscow airports and passengers in transit handled by them. It assures the performance of the following functions [28]:

-- the sale of air tickets for 1100 flights a day;

-- the taking of orders for seat reservation and the preliminary sale of tickets (for 30 days);

-- the restoration in the computer memory of information about airplane seats and the issuance of information about the presence of free seats on non-stop and one-stop routes;

-- the accumulation of statistical data on passenger transportation;

-- the reproduction on displays of data on the presence of seats on flights departing from Moscow airports in the next 5 days;

-- the issuance of information to various services of Aeroflot.

Characteristic of an airplane seat reservation system is considerable irregularity in the arrival of requests for service in different periods of the year, month and day. The average number of inquiries is up to 15,000 per hour, and the coefficient of irregularity of the mean number of inquiries per hour in the course of the year is about 7. The waiting time for an answer to an inquiry must not exceed 3 seconds.

An enormous volume of information must be preserved in the system. In that case the requirements as regards the frequency of access time to different files are substantially different. Actually, the volume of information needed to service the flow of requests in a real time scale (information about seats, rates, distances, cost of tickets, etc) is 2×10^6 bytes. Since a considerable portion of that information changes continuously, it is advisable to put it in the main memory with a short access time. Information about passengers in transit and preliminary reservation of seats in a volume of 5×10^6 bytes changes more rarely and therefore is put on magnetic drums and disks. Finally, for the recording of statistical information on conducted operations in a volume of over 30×10^6 bytes per day, magnetic stores are used.

The hardware complex of the "Sirena-1" automated system consists of the following equipment:

-- two M-3000 universal digital computers in a maximally expanded modification (the total capacity of the main memory is 3.6×10^5 bytes--six main memory modules and four read-only modules, constituting the basis of the computer complexes);

-- external storage units;

-- input-output units;

-- distribution-conversion devices;

-- complex of data transmission devices;

-- terminal complexes.

The data processing system is so constructed that it assures high reliability and survival of the system and also adequate reliability of the results of calculations. The mean time to failure in the system reaches 5 years, and not more than 1 incorrect ticket is issued per 100,000 sold. The data transmission equipment serves to connect the electronic computer with the terminal complexes through standard telephone and telegraph channels and physical lines of communication. In addition, a special device in the data transmission equipment permits increasing the reliability of the transmitted information to 10^{-7}. Under normal conditions the distribution-conversion device assures connection with more than 500 users.

The terminal complexes include panels, reference-information displays and telegraph equipment. The panels are installed in agencies, airports and ticket sales points in Moscow and also Aeroflot agencies in other cities. They provide a set of messages in accordance with the requirements of the user, visual control of the message on the panel screen, the transmission of messages to the line, obtaining and monitoring the reply, and also automatic printing of airplane tickets on blanks of a special form.

In proportion to the accumulation of experience in operating the "Sirena-1" system the range of tasks solved with its help will be substantially expanded.

The principles of organization of the "Sirena-1" system and the structure of its hardware complex can also be successfully used in other queueing systems with seat reservation, for example, in rail transport, in hotels, etc.

8.4. Example of an Automated Control System for a Sector of Industry (OASU)

The OASU represents a combination of administrative and economical mathematical methods, means of computer technology and communications which permit agencies of control of ministries and departments to accomplish control of a sector.

The creation of an OASU is dictated by profound qualitative and quantitative changes that have occurred in industry during the transition to the sector principle of control.

The OASU must assure the selection of the most correct, economically substantiated processes in relation to both problems of the long-range development of the sector and the operational solution of problems arising in the course of fulfilment of the established plan.

It most ministries and departments the most important tasks solved within the framework of the OASU are tasks of practical accounting and control, of material and equipment supply, bookkeeping and analysis of economic activity and tasks of technical and economic planning. One of the principal problems in the development of the OASU consists in the accomplishment of optimum tasks in planning on the basis of methods of mathematical programing. Required is the development of economic-mathematical models of the functioning of the sector as a whole, assuring optimization of plans for the development of sectors of the national economy. Needed is the development of an optimum system of technical and economic indicators, which will create the prerequisites for work in the area of standardization and unification of documentation.

As an example we will examine the sector automated system of the Ministry of Instrument-Making, Automation Equipment and Control Systems, "ASU-Pribor" [Avtomatizirovannaya sistema upravleniya otrasl'yu priborostroyeniya--Automated Management System for the Instrument-Making Sector] [6].

The main tasks of "ASU-Pribor" are tasks of long-range and annual technical and economic planning under the conditions of the new system of planning and economic stimulation. The "ASU-Pribor" system was constructed with consideration of the existing structure and specialization of functional and production administrations and embraces over 280 tasks of planning, accounting and analysis, distributed over 10 subsystems of the first line: long-range planning, the development of the sector, technical and economic planning, operational control, control of material and equipment supply, control of procurements, control of marketing, control of financial activity and bookkeeping, planning, accountng and analysis of labor and wages, and planning and personnel records.

Tasks in the improvement of control of capital construction, scientific research work, quality of product, the technical servicing of production, etc, are also solved in the second line of the system.

The subsystem "Long-range planning of the development of the sector" solves four tasks: determination of the long-range requirements for production by consolidated groups; the formation of alternatives of the development of enterprises of the subsector; optimization calculations of alternative long-range plans of subsectors; economic-mathematical analysis of calculations and the working up of recommendations.

The subsystem "Technical and economic planning" includes four tasks of production planning: determination of the optimum production plans of the enterprises; determination of the production capacity of the enterprises; determination of the khozraschet indicators; calculation of the principal technical and economic indicators of the enterprises, which are solved twice a year during the compilation of plans and the approval of plans for the following year.

The largest number of tasks is solved in the subsystem "Operational control": monthly analysis of fulfilment of the plans for profit, labor productivity, capital construction, very important work on new technology, the production of consumer goods and the number of personnel. The level of rhythmicity of sales of production is analyzed every 10 days, and the fulfilment of the plan for sales of finished product--daily and on the basis of the results for each month.

A combination of the long-range and accounting technical and economic indicators of production serves as the informational base of the system. In the subsystem of provision of information, methods have been worked out for the organization of data files and their storage and control, which assure an interconnected solution of an entire group of tasks. This eliminates parallelism and duplication of information in the files. The total volume of information processed in the IVTs "ASU-Pribor" in the course of a year amounts to about 183 million bits, and that issued by the administrative organization of the ministry--to almost 336 million bits. The input data arrives from enterprises and organizations of the sector on documents of 94 forms. Standardized operational messages are transmitted by enterprises to the computer center over communication lines. The development of new documentary forms has been accompanied by the exclusion of excessive information. Thus the accounting and statistical reporting has been reduced by about 15,000 indicators in a year, and the summary quotas for the expenditure of materials and set-making parts are now given in documents in two forms instead of 38. In the system 57 classifiers are used, including 30 local, 2 sector, 5 all-union and 20 intended for the ASUP.

Envisaged is the connection and interaction of the "ASU-Pribor" with enterprise management systems on a normative base, data flows and tasks to be solved.

A hardware complex assures accomplishment of the collection, transmission, processing, storage, issuance and depiction of data in the sector management system and the connection of the "ASU-Pribor" with enterprises and organizations of the sector.

"Minsk-22," BESM-4 and "Ural-14" electronic computers were used in the first line of "ASU-Pribor." The use of third-generation computers in the second line of the ASU permits creating for the OASU multiprocessor systems realizing, along with batch data processing, the automatic input and output of data in a line of communication. In that case one of the processors (or group of processors) must be oriented toward batch data processing, and the other toward the performance of functions requiring work in a real time scale.

A network of interconnected and informational points of communication, equipped with users' telegraphic installations, has been created for the transmission of operating information to sector enterprises.

APD-AM telemechanical equipment permits data transmission over telephone lines to a BESM-4 computer from a user who records the data on perforated tape. The transmission is accomplished by a 7-element code at a rate of 600-1200 bauds and with a reliability of transmission not worse than 10^{-6}. The coupling equipment permits feeding data to the computer from a commutator of telephone communication channels (up to 64 channels) and from data transmission equipment over telephone channels (up to 16 channels) and the issuance of data from a computer to those devices. During work with external channels regimes of program interruption and turn off are used in the computer.

Standard-reference information is sent to the OASU by enterprises by main in the form of files of perforated cards (sorted and checked) together with lists of all the perforated cards printed on a tabulator. The annual volume of input data of the subsystem of technical and economic planning and analysis of economic activity alone is equal to 0.16×10^{10} bits.

For visual depiction of information, portable panels of the "Ekran" type are installed in the equipment of the ministry. They permit workers of the organization to obtain from the computer upon request information on the screens of electron-beam instruments.

The software of the "ASU-Pribor" represents a complex of programs for regular use. For special software it is necessary not only to develop programs for the solution of specific problems but also to assure the creation of integrated data processing systems. In the development of an OASU the designer needs means of programing: several algorithmic languages and translators from them, standard programs of standard processing procedures and compiling systems. The volume of software of the first line of the "ASU-Pribor" is 210,000 commands. Therefore in the development of the OASU automation of the programing must be used. The latter is envisaged in three directions: the creation of libraries of standard programs of standard data processing procedures, the introduction of universal algorithmic languages and the development of standard planning solutions.

With the introduction of the "ASU-Pribor" in the Minpribor, optimized plans of enterprises, subsectors and the sector as a whole are being calculated.

Computer-created alternatives of drafts of production plans for 103 instrument-making enterprises have confirmed the possibility of increasing the output of production by 25 million rubles and the profit plan by 9 million rubles, with additional capital investments totaling only 374,000 rubles.

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[Article by L.F. Borodin, E.N. Valendik and A.S. Mironov]

[Text] A summary is given of the results of studies involving the use of microwave radiometry in solving problems of the fire protection of forests and peat bogs. Information is given on the microwave radiation of forest fires. By means of airborne microwave radiometers it is possible to single out clearly the key tactical sections of a fire under conditions of heavy smoke. Experimentally obtained spectrum curves are presented for the absorption coefficient and radiating power of peat. An estimate is given of the microwave radiation spectra of peat piles with latent hazardous heat sources. A demonstration is given of the fundamental possibility of estimating the fire hazard level of areas covered with forests and peat bogs by spectral measurements of their radiating power.

Introduction

Forest and peat fires come under the heading of hydrometeorological phenomena which are especially hazardous for the national economy, which has predetermined the urgency of the objective of finding efficient methods of detecting and mapping fires under complex weather conditions with the existence of the masking effect of smoke. Under the heading of problems of first-level importance must certainly come the problems of estimating the fire hazard of forest areas in good time and reliably, as well as the determination of sections of peat bogs and peat piles having deep spaces with critical heating.

Modern aerospace and mobile radiophysical equipment make it possible to use for the purpose of solving the above-mentioned problems methods based on the reception of the self-radiation and reflected radiation of natural formations in the microwave [1-2, 11-13, 19], IR [4-6, 9-10] and optical [3] bands.

Of course, the varying conditions of irradiance of subjects of study have practically no influence on the results of aerospace measurements in the microwave band. Radiowaves in the SHF and UHF bands have comparatively good penetrating power through clouds, aerosols (smoke) and ground covers. At the same time definite difficulties are encountered in making measurements in the microwave band with high angular resolution, as well as in obtaining "microwave photographs" of large areas with a good degree of detail. Let us point out that quite serious is the problem of efficient documentation and analysis of microwave, IR and optical images of the underlying surface, as well as matching them with sketch measurements and a map.

Research by microwave radiometric methods on burning forests and peat bogs, from on board an aircraft laboratory, was begun in the outskirts of Moscow in the summer of 1972, during the time of the outbreak of large-scale forest and peat fires.

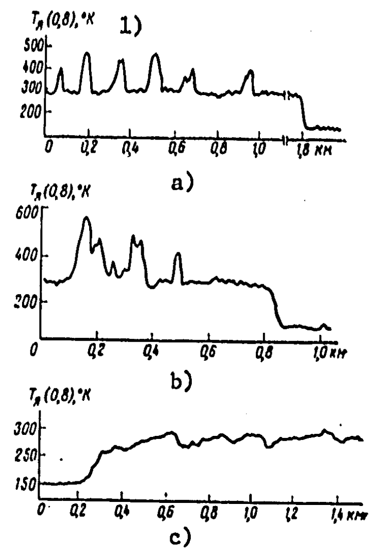

Figure 1. Radioluminance Temperature Profiles with an 0.8 cm Wave, Obtained in Flights: a--over a series of burning piles; b--over a burning peat bog; c--over a forest fire in peat bogs. The 150°K levels are the gauge levels (obtained in flying over a water surface).

Key:

1. T_{ya} = luminance temperature

In fig 1 are shown radioluminance temperature profiles for burning piles of peat, a peat bog and a section of a forest in a peat bog, obtained from on board an IL-14 aircraft laboratory in the area of Shatura in 1972, by means of an 0.8-cm-band radiometer. The increase in the radioluminance temperature in the first case was 100 to 200°K, in the second 100 to 300°K and in the third 30 to 70°K [1-2].

The results gotten in 1972 stimulated theoretical and experimental studies aimed at revealing the radiophysical essence and microwave characteristics of sources of forest and peat fires, at studying the radiophysical characteristics of peat and the soil cover, at studying the screening properties of treetops and smoke, and at developing remote methods of revealing sections of peat bogs having deep spaces with critical heating, as well as methods of making a non-contact estimate of the moisture content of the soil cover under a forest cover and in open areas, as one of the most important characteristics of the fire hazard of forest and peat bog areas [1-2,11-14,19].

On the applied level this research has proven useful, first for precisely defining the place of radiophysical methods in the problem of protecting forests and peat from fire, and second for developing recommendations on the future furnishing of forest patrol aircraft with radiophysical equipment for the purpose of determining the location and key characteristics of fires under conditions of heavy smoke and screening by the forest, as well as for the purpose of making an objective estimate of the fire hazard of individual sections of large areas.

1. Microwave Radiation of Forest Fires

In the absence of fire, the radioluminance temperature of a dense forest is close to the thermodynamic temperature of the air at the level of the treetops, and its radiating power equals 0.92 to 0.99 [7,8,20], i.e., differs but slightly from the radiating power of an absolutely black body.

Above a burning forest the intensity of microwave radiation increases, and the mechanism for formation of the radiation, just as the amount of the increase in radioluminance, depends on many factors, and, primarily, on the kind of fire (low-level, high-level and underground [4]).

In a fleeting low-level fire increases in the radioluminance temperature over the burning area are not too high, since the underlying surface does not get to burn, and the screening influence of the treetops for microwave radiation is considerable. Radioluminance contrast increases in sparsely wooded areas and in open areas where grass and windfallen trees are burning.

A change in the fire from a fleeting low-level one to a steady one, and even more so to an underground one, is accompanied by a rise in the luminance temperature as a consequence of a growth in the role of the radiation of the heated soil and of the burning topsoil cover, as well as of the flames' radiation.

The radioluminance temperatures of sections of high-level fires rise considerably, which is related to the high burning intensity, a drastic reduction in the screening cover of the forest and smoke, and also the presence in the convection column above the fire of a considerable number of particles which continue to burn (pieces of charcoal, twigs, pine needles, and the like).

Taking into account the features of the propagation of SHF and EHF radiowaves in different media (depth of penetration of electromagnetic energy into the ground, influence of solid carbon particles on the flame's radiation spectrum), it is possible to expect an increase in radioluminance contrast of fires above the surrounding non-burning background as the wavelength is shortened in the 0.8 to 2 cm range, which has been confirmed by model estimates and experimental results.

In [12] calculations were made of the radiation spectrum of the source of a fire screened by a layer of smoke and treetops. The basic results were gotten on the supposition that the flame, smoke and treetops represent distinctly separate homogeneous layers filled with particles which are small as compared with the wavelength, with known temperature and dielectric constant. In particular, the complex dielectric constant of the particles filling the "treetop" layer was selected as close to the dielectric constant of fresh water.

An analysis of this model, taking the results of [8] into account, has shown that the radiating power of the flame in the microwave band increases with an increase in the size and concentration of the particles and the height of the flame, and also with a shortening of the wavelength at which measurements are made. The screening effect of the smoke trail increases as the thickness of the smoke layer and the size and concentration of the smoke particles increase, and as the wavelength is shortened. Finally, the weakening effect of the forest on the microwave radiation of the flames grows intensely with shortening of the wavelength and an increase in the degree of intertwining among treetops.

Numerical estimates made while taking into account the above limitations have shown that "flame - smoke - treetop" (low-level fire) and "flame-smoke" (high-level fire) models lead to identical results in the sense of the existence of a radiating power maximum in the 0.8 to 1.5 cm range. Furthermore, the value of the radiating power (with an extreme wavelength) varies in the first case within the range of 0.6 to 0.2, and in the second within the range of 0.95 to 0.4. It should be mentioned that with smoke particle dimensions smaller than 10 microns their influence on flame radiation in the microwave band is negligibly slight.

The screening influence of treetops was estimated on the assumption of small (as compared with the wavelength) sizes of "filling particles." Taking into account the dissipation of radiation for a medium filled with long thin cylinders (needles of coniferous trees) results in a 10 to 30 percent adjustment in the attenuation factor.

In fig 2 are given examples of brightness temperature profiles for one and the same fire source, obtained by means of an airborne 1.35-cm-band radiometer.

The pattern in fig 2a refers to the case of flying over the source of the fire at an altitude of 150 m in the direction of spreading of the smoke trail. Here three areas of the source are clearly delineated: the rear, the burnt-out section and the front of the fire. The front of the fire establishes the area with the greatest increase in brightness temperature (60 to 70°K). Then comes an area in which the increase in brightness temperature is reduced to 10 to 15°K; this is the burnt-out section. The increase in brightness temperature over the rear of the fire is 20 to 30°K.

In fig 2b are given the results of en-route measurements of brightness temperature from the same altitude of 150 m, but while flying over the fire in the direction perpendicular to the smoke trail. Here are clearly delineated in addition two other tactical sections of the fire--its left and right flanks. The increases in brightness temperature of these two burning areas are approximately equal to one another and amount to a value on the order of 60°K. The burntout section has the same characteristics as in the case in fig 2a.

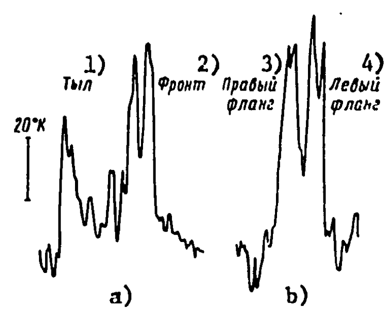

Figure 2. Profiles of Rise in Brightness Temperature with a 1.35 cm Wave, Gotten While Flying Over the Source of a Low-Level Fire: a--along smoke trail; b--across smoke trail

Key:

1. Rear	3. Right flank
2. Front	4. Left flank

The brightness temperature profiles shown in fig 2 are characteristic of steady low-level fires, which are described by the follwing key traits.

The width of the intensely burning edge of the fire around its outline varies within the range of 1 to 3 m.

The rate of spreading of the front edge of the fire equals 1 to 2 m/min, of the flanks 0.6 to 1 m/min, and, finally, the rate of advance of the rear edge of the fire is within the range of 0.2 to 0.6 m/min.

The maximum height of the flames at the front edge of the fire reaches 1 to 2 m, and 0.3 to 0.6 m on the flanks and in the rear.

The rise in the flames' thermodynamic temperature at the fire's edge equals 800 to 900°K. At the same time the rise in the thermodynamic temperature of the topsoil cover and the soil's surface layer at the fire's burntout section equals 30 to 80 and 10 to 25°K, respectively.

Fires with these characteristics originate, for example, in areas covered with dried-up standing dark conifer forest timber with mosaic interspersing of leafed and dark conifer sections of the forest. These sections are characterized by the following supplies of combustible materials: topsoil cover dry mass--0.5 to 0.9 kg/m^2; deadwood trees and dead standing wood--100 to 150 m^3/ha.

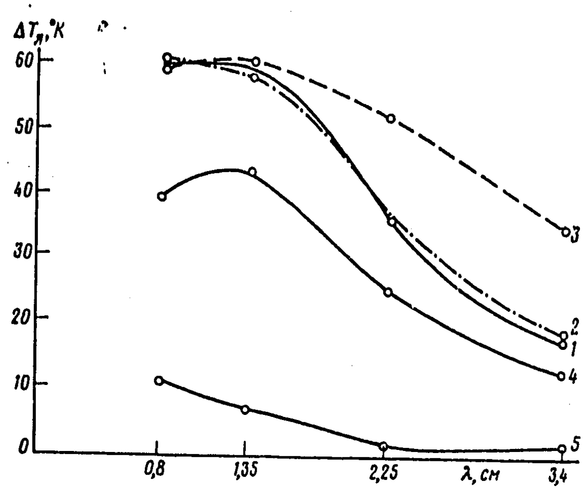

Figure 3. Averaged Spectral Characteristics of Tactical Sections of a Fire: 1--front; 2--left flank; 3--right flank; 4--rear; 5--burnout section

In fig 3 are given spectral characteristics, averaged for a series of approaches, of rises in the radioluminance temperatures of the front, flanks, rear and burntout section of a fire. These results were gotten by averaging the maximum values of radioluminance rises recorded in flying over different sections of the same source with different courses. The total error in measuring the radioluminance contrast of the averaged data does not exceed 2°K.

In fig 3 attention is drawn by the presence of a marked maximum in the radiation spectrum of the fire's rear with a wave close to 1.3 cm in length.

An analysis of the dimensions of experimentally obtained profiles of the type shown in fig 2 has shown that in many cases the size of the response from the front, flanks and rear of the fire at the level of the underlying surface and at the level of 0.5 from the maximum considerably exceeds the dimensions of the antenna spot at the 0.5 level. This fact testifies to the fact that the intensely burning edge of the fire, 2 to 3 m wide, is far from the sole factor determining the intensity of the microwave radiation of the source of the fire. Judging from the experimental data, a considerable (if not the main) contribution to radiation characteristics must be made by the burning topsoil cover and the heated soil.

On the basis of the data obtained the conclusion can be drawn that it is possible to use the microwave method for the purpose of delineating the outlines of forest fires and estimating the intensity with which they are burning by means of shuttle flights over fires [11]. The use of airborne microwave and IR scanning equipment will make it possible to solve the problem of charting large forest fires concealed by thick smoke with minimal expenditures of time.

The importance of developing effective methods for combating forest fires dictates the need to make from on board an airplane complex remote measurements of the characteristics of fires being monitored and to compare their results with synchronous quantitative ground observations of the thermodynamic and other parameters of sources.

2. Microwave Self-Radiation of Peat Structures

The problem of detecting and preventing a peat fire is closely related to the ability to estimate the temperature and moisture content profile of peat structures. The solution to this problem by microwave radiometric methods as applied to different types of soil and subsoil has been discussed in a number of papers (cf., e.g., [7,8,16,17]).

Of course, for the purpose of estimating the temperature and moisture content characteristics of a medium it is necessary first of all to know its radiating power, $\kappa(\lambda)$, and absorption coefficient, $\gamma(\lambda)$.

The radiating power of peat, as of other types of soil and subsoil, is a function of the dielectric properties of the medium and the roughness of the surface. In turn, the dielectric properties of the medium depend on the moisture content, density, and granulometric and mineralogical composition.

The absorption coefficient is also determined by the dielectric properties of the medium. The radiating power and absorption coefficient depend on the wavelength, viewing angle and polarization of the detected radiation.

A determination was made of the radiating power of peat in the $\lambda = 0.8$ to 60 cm wavelength range by measuring the radioluminance temperature of an evenly moistened and evenly heated peat pile whose dimensions were considerably greater than the dimensions of the "spot" of the main lobe of the antenna. The moisture content and thermodynamic characteristics of the peat pile were monitored by contact methods [19]. The results of processing the experimental data are given in fig 4. It follows from these curves that the radiating power of peat with a moisture content of 40 to 80 percent has a minimum in the 10 to 20 cm range. Furthermore, this minimum is more extreme the greater the moisture content.

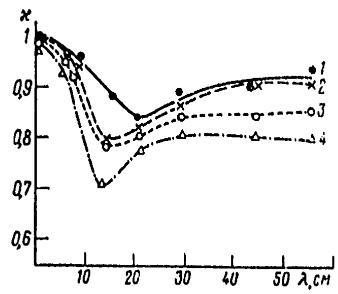

Figure 4. Spectral Characteristics of the Radiating Power of Peat with Moisture Content by Weight of: 1--45 percent; 2--54 percent; 3--67 percent; 4--78 percent

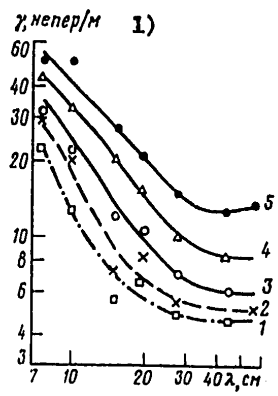

Figure 5. Spectral Characteristics of Absorption Coefficient in Peat with Moisture Content by Weight of: 1--40 percent; 2--53 percent; 3--63 percent; 4--70 percent; 5--73 percent

Key:

1. γ, nepers/m

Let us note that the presence of a minimum in the radioluminance temperature spectrum of peat structures was confirmed during the course of measurements of the microwave self-radiation of peat bogs from an IL-18 aircraft laboratory [13].

In fig 5 are shown curves characterizing the behavior of the absorption coefficient of peat in the 7 to 60 cm wavelength range [13,19]. These curves were obtained by measuring the relative level of thermal radioemission of a layer of peat laid onto a thin sheet of radiotransmissive material placed above an antenna aimed into the sky. The absorption coefficient was computed on the basis of experimental data, utilizing the equations for the radiating power of a laminar medium in [15].

An analysis of the experimental spectra of the absorption coefficient in peat has shown that, as in soil and subsoil, it increases with an increase in the moisture content of peat and with shortening of the wavelength. The inverse value of the absorption coefficient characterizes the depth of penetration of an electromagnetic wave into peat, and, consequently, the ability to indicate a change in temperature within the pile. For example, it follows from the curves in fig 5 that with a fixed moisture content of $w = 40$ percent the depth of penetration of the wave increases approximately fivefold as the wavelength changes from 7 to 40 cm. A 40 to 73 percent increase in the moisture content of peat is accompanied by an approximately 2.5- to threefold reduction in the depth of penetration.

One of the promising trends in seeking an explanation of the experimentally established fact of a reduction in the radiating power of peat in the 10 to 20 cm wavelength range is the trend involving the theory of dissipation of electromagnetic radiation in internal inhomogeneities of a medium with high hygroscopicity. Furthermore, of interest are studies of the problem of the dissipation of electromagnetic radiation caused both by the structural inhomogeneity of peat (lumps, fibers, etc.) and by spatial fluctuations in its dielectric constant.

Let us assume that a peat medium represents a laminar structure, and the dielectric constant of each layer differs but slightly from the mean value. Let us assume also that fluctuations in the dielectric constant are of a random nature and are characterized by a correlation function of the form:

$$B(h) = \sigma^2 \exp\left[-h/l\right], \tag{1}$$

where σ^2 is the variance of the dielectric constant and ℓ is the correlation interval.

With these assumptions, based on the results of [21], it is possible to find an equation for estimating the radiating power of an isothermal medium:

$$\varkappa = \frac{1-r}{\frac{1+r}{2} + \frac{1-r}{2}\sqrt{1 + \frac{\sigma^2}{\gamma_1 l\left[1 + \left(\frac{\lambda}{4\pi n l}\right)^2\right]}}}. \tag{2}$$

Here r is the Fresnel reflection coefficient with the mean value of the dielectric constant; γ_1 is the component of the absorption coefficient caused by heat losses; λ is the wavelength in free space; and n is the mean value of the medium's refractive index.

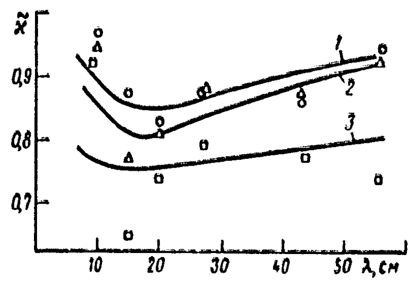

Figure 6. Spectral Curves for Radiating Power of a Peat Pile with Moisture Content by Weight of: 1--45 percent; circles--experimental data; 2--53 percent; triangles--experimental data; 3--78 percent; squares--experimental data

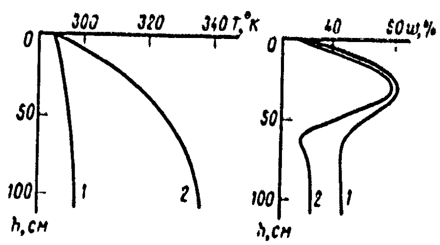

Figure 7. Temperature and Moisture Content Profiles of Cold (1) and Heated (2) Sections of a Peat Pile

Having specified the moisture content and mean value of the dielectric constant of peat, as well as the values of the absorption and refraction coefficients corresponding to them (fig 5), it is possible, by sampling values of ℓ and σ^2 , to reach the point where the shape of spectral curve (2) agrees with the experimental data on the radiating power of peat. In fig 6 the results of these calculations are given for three values of the moisture content of peat. Here it turned out that the value of σ^2 (1) grows with an increase in the mean value of the dielectric constant, which, in turn, increases as the moisture content increases. At the same time, the value of parameter ℓ is lowered with an increase in moisture content, which is physically explicable (bonds between peat particles result, when weakened, in reduction of sizes of their associations.)

The relatively great difference in the calculated and experimental curves in fig 6 in the shortwave region can be explained by the dependence, not taken into account, of the dielectric constant on wavelength.

Further experimental and theoretical research aimed at explaining the anomaly discovered in the self-radiation spectrum of peat bogs has been quite promising from the viewpoint of refining modern views on the mechanism for the formation of radiothermal emission in fibrous, porous and spongy media which are non-uniform in terms of depth, including heterogeneous media with high hygroscopicity.

3. Indication of Deep Sources of Self-Heating in Peat Piles

The existence of changes in the thermodynamic temperature of a medium can be estimated from the spectrum of variations in brightness temperature. As a first approximation, the brightness temperature, $T_{ya}(\lambda)$, at the wavelength, λ, is determined by the equation in [14]:

$$T_{a}(\lambda)=\varkappa(\lambda)\left\{T_{0}+\frac{T_{0}'}{\gamma_{0}(\lambda)}\left[1-\frac{\gamma_{0}'(\lambda)}{\gamma_{0}^{2}(\lambda)}\right]+\frac{T_{0}''}{\gamma_{0}^{2}(\lambda)}+J_{3}(\lambda)\right\}, \tag{3}$$

where T_0, T_0' and T_0'' are the values of the thermodynamic temperature profile and of its first and second derivatives at the surface; $\gamma_0(\lambda)$ and $\gamma_0'(\lambda)$ are the values of the absorption coefficient and its derivative at the surface; and $J_3(\lambda)$ is the remainder.

Equation (3) was arrived at as the result of very simple transforms of the energy transport integral (threefold integration by parts) [14,19].

From equation (3) a calculation was made of the radioluminance temperature spectra for self-radiation of a pile for two different laws of variation of the temperature and moisture content of peat with depth (cf. fig 7). Values of the radiating power and absorption coefficient were found from the curves in figs 4 and 5. The results of calculations of T_{ya} are given in fig 8 (curves 1 and 2). Here also are given the experimental values of radioluminance temperatures, as well as the limits of the measurement error and systematic errors (vertical segments). The maximum difference in radioluminance temperatures between the cold and heated sections of a pile, on the order of 20°K, is observed in the UHF waveband.

Analysis of the data obtained shows that the microwave self-radiation spectrum of peat depends essentially on the distribution by depth of the peat's temperature and moisture content.

This fact can serve as the basis for developing non-contact methods of indicating the temperature and moisture content characteristics of peat piles.

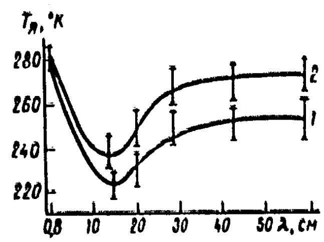

Figure 8. Spectral Curves of Radioluminance Temperature of Cold (1) and Heated (2) Sections of a Pile: solid curves--calculation results; vertical marks—experimental data

Unfortunately, the solution to this problem has encountered a number of difficulties, associated with the existence of masking phenomena and effects. Primarily, let us note that, according to visual observations and the data of contact measurements, the structure of the top layer of peat in piles up to a depth of at least 50 cm is rather varied. Here is observed the alternation of interlayers of dry and wet peat, whose thickness varies from one section of the pile to another. Furthermore, the process of self-heating is accompanied in many instances by an increase in the moisture content of peat before the zone of the self-heating source, which is related to the condensation of water vapors diffused from the maximum heating zone (the source "expels" the moisture), cf. fig 7. This fact, on one hand, results in equalization of the moisture content of interlayers of peat in the surface layer (intensification of the moisture transport process), and on the other causes a reduction in radiating power at the longwave end of the spectrum for those sections of peat piles in which depthwise changes in temperature are observed.

Finally, let us note that the existence of a minimum in peat's radiation spectrum also complicates the solution to the problem of indicating depthwise temperature anomalies in peat piles.

4. Fire Hazard Level

The fire hazard of forest areas is determined by the moisture content of the topsoil and vegetation cover. With a critical moisture content (less than 25 percent) of dead vegetation, mosses, lichens and other conductors of combustion [22,23], favorable conditions are created for the origin and spreading of a low-level fire. At the same time, with a treetop moisture content of less than 80 percent, the serious threat arises of the low-level fire's becoming a high-level one, which represents the greatest hazard, both from the viewpoint of the rate of the fire's spreading, and also from the viewpoint of the destruction of forest flora and fauna.

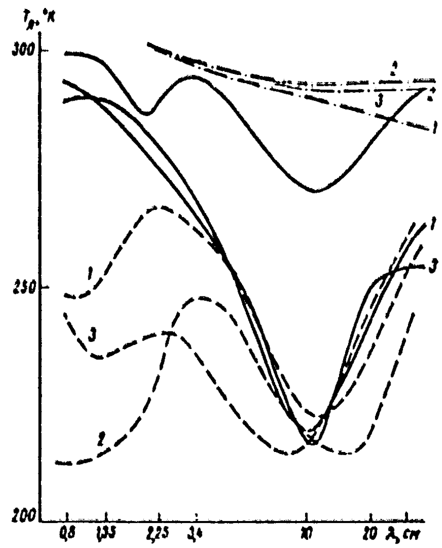

Figure 9. Spectral Characteristics of Burnt Clearings (Dot and Dash Line), Peat (Solid Curves) and Sphagnum (Dotted Line) Bogs in the Process of Drying Out and Being Wetted by Precipitation: 1--during rain; 2--after heavy rain; 3--two 24-hour periods after rain

For the purpose of estimating the fire hazard (estimating the moisture content of combustion conductors), at the present time indirect methods are employed, involving the analysis of weather station data, in particular, on precipitation for a specific period of time [18.24-27]. Unfortunately, the use of all these methods for the purpose of estimating the fire hazard in the practice of forest conservation does not lead to perceptible results. In the meanwhile, no fundamental difficulties have been encountered in directly estimating the moisture content of "open" forest areas of the glade and bog type, etc., by measuring the microwave self-radiation spectrum from on board an airplane. For example, in fig 9 are shown curves illustrating the changes in the spectral characteristics of bogs and glades (burnt clearings) in the process of drying out and being wetted by precipitation. These data, obtained in 1977 from on board an IL-18 airborne laboratory, testify to the feasibility of employing microwave radiometric methods for the purpose of estimating the moisture content of the topsoil cover and the moisture supply of bogs (ground water level). Let us pay attention to the presence of a brightness temperature minimum in the radiation spectrum of a peat bog with 10 to 20 cm waves and of a minimum at the shortwave end of the radiation spectrum of a sphagnum bog.

The dependence of these spectra on weather conditions is clearly traced in fig 9.

Finally, let us stress that the detection of overly moistened sections of forest areas, as well as knowledge of the ground water level in bogs, are decisive both in estimating the fire hazard of swampy forests, and in evaluating factors hindering the spread of local forest fires to large areas [28,29].

For the purpose of obtaining quantitative relationships objectively estimating the fire hazard of typical forest sections, intensification of experimental and theoretical research is needed. Useful here are the methods and results described in [7,11,13,16,17].

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GEOPHYSICS, ASTRONOMY AND SPACE

SOYUZ VEHICLE'S PARACHUTE BRAKING SYSTEM DESCRIBED

Paris AIR & COSMOS in French 11 Nov 78 pp 51, 56

[Article by Serge Berg]

[Text] The parachute braking system of the Soyuz vehicle and its operation are described for the first time in AVIATZIA I KOSMONAVTIKA, monthly publication of the military air forces of the USSR (September issue). The article was written by the very one who designed the system, N. Lobanov, doctor of technical sciences, and laureate of the Lenin Prize and other state prizes.

The function of the parachute braking system is to reduce the speed of the Soyuz from 240 meters per second (864 kilometers per hours), at about 12 kilometers altitude, to some 6 meters per second (29 [sic--21.6] kilometers per hour) near the ground when the Soyuz puts down on the earth; Lobanov reminds his readers that the vehicle can also put down at sea.

If everything proceeds normally the braking sequence is as follows: The braking parachute (with area of only 14 square meters) deploys at about 11,000 to 9,000 meters altitude by virtue of small extracting parachutes which are themselves deployed after ejection of the parachute container lid (controlled by a barometric device). When the descent velocity of the Soyuz cabin is not more than 90 meters per second (324 kilometers per hour) the braking parachute extracts, from the container, the main parachute which progressively unfolds. The braking parachute detaches itself from the main parachute. In 4 seconds the speed is reduced to 35 meters per second (126 kilometers per hour) and the main parachute is then fully deployed.

The area of the main parachute is 1,000 square meters; it is folded inside a container of 0.3 cubic meters. The maximum load to which the main parachute is subjected does not exceed 13 tons. When the main parachute is fully deployed explosive bolts eject the thermal shield which protects the lower portion of the cabin exposed to the thermal flux of reentry; this shield, incidentally, covers the nozzles of the retro-rockets which provide final braking of the cabin in order to assure soft contact with the ground.

After ejection of the thermal shield there occurs a rebalancing of the cabin upon two symmetrical suspension lines; the cabin then assumes a vertical position instead of the inclined one it previously assumed. At about 1.5 meters from the ground the motors of the cabin retro-rockets are automatically ignited. Finally, the cosmonauts cause one of the parachute suspension lines to be jettisoned so that the parachute cannot fill with wind like a sail and drag the cabin if there is considerable wind on the ground.

In the event of accident emergency procedures are provided.

If the main parachute container lid does not open at the planned altitude, Lobanov explains, an automatic control causes the container of the reserve parachute to open and it fully deploys in 4 seconds; its area is 574 square meters (container volume 0.2 meter). As the reserve parachute will open at a lower altitude when the relative speed of the cabin will be lower it is not necessary to utilize a braking parachute. However, since the area of the reserve parachute is half that of the main parachute the cabin's landing speed before ignition of the retro-rockets will be greater--8 to 11 meters per second (29 to 40 kilometers per hour). The landing is therefore rougher but not dangerous, Lobanov states.

It might also happen that the braking parachute does not cause emergence and deployment of the main parachute; for example, because of damage to the braking parachute, or blocking of the main parachute as the result of deformation of the container due to abrupt change in pressure when the container lid is ejected. When that occurs the interior pressure of the container equalyzes with that of the surrounding atmosphere and the walls of the container are subjected to a load of 10 to 11 tons per square meter. Depending upon the altitude at which the lid is ejected the pressure drop can cause a load of 5 to 6 tons per square meter. In such case, 24 seconds after the beginning of the sequence, the braking parachute is going to be separated from the main parachute, then enabling the reserve parachute to be deployed.

Provision has also been made for the possibility of incomplete deployment of the main parachute although that eventuality is extremely remote. In such event a device enables the main parachute to be detached from the cabin, enabling the reserve parachute to be extracted and deployed.

Finally, if there is a breakdown of the landing retro-rockets, the cabin would then touch the ground at a speed of 6 meters per second if there is no wind, or 4 meters per second if there are ascending currents, or 8 to 9 meters per second if the currents are descending. No emergency device has been provided for this case. The shock will be more or less rough (depending upon the nature of the ground) but will be in part compensated by the shock absorbers attacked to the cosmonauts' seats.

Lobanov also reminds his readers that the Soyuz vehicle has a rescue system (SAS) for the crew in the event of malfunction of the rocket at take-off.

The SAS motors then separate the vehicle from the rocket and project it to the side--rather high--in order that the two extraction parachutes (which are of different areas), and then the main parachute can be deployed.

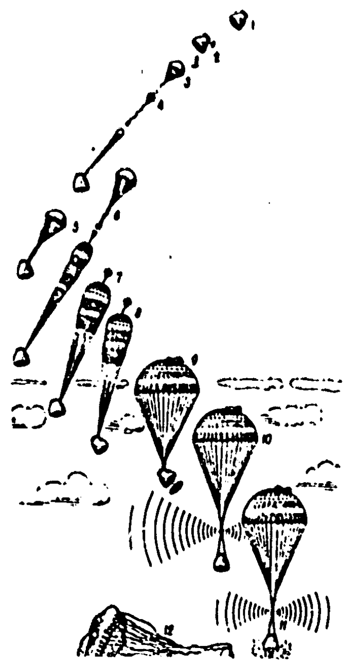
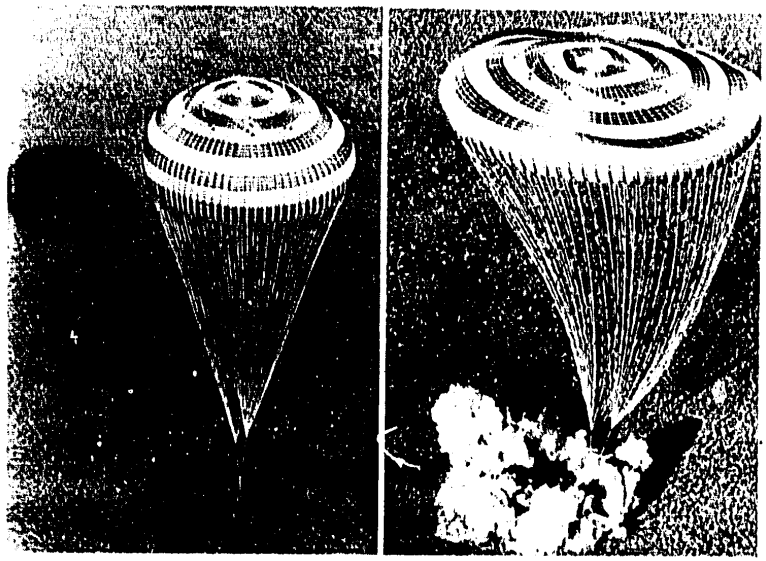


Diagram of operation of parachute braking system of the Soyuz vehicle. 1--Descent module of the Soyuz, 2--Parachute container lid ejection, 3--Large area extraction parachute, 4--Small area extraction parachute, 5--Braking parachute, 6--Separation of braking parachute and emergency of main parachute, 7--Main parachute begins to fill, 8--Deployment of main parachute, 9--Ejection of thermal shield, 10--Rebalancing of capsule on symmetrical suspension lines and commencement of transmission by the radio locator beacon (attached to suspension lines), 11--Ignition of retro-rockets for soft landing, 12--Unfastening of half the straps of the main parachute.



Very good photos of the descent of the main parachute of the Soyuz 29 vehicle's cabin in September 1978 with Valery Bykovskiy of the USSR and Segmund Jahn of the GDR on board. On left: a few instants before landing; the two cabin suspension lines, crossed at the level of the beacon, can be seen distinctly. On right: at very moment of cabin's impact, in a cloud of dust (caused in party by the jets of the final braking retro-rockets)

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GEOPHYSICS, ASTRONOMY AND SPACE

USSR

BREAKTHROUGH IN READAPTATION OF COSMONAUTS TO GRAVITY DISCUSSED

Paris AIR & COSMOS in French 11 Nov 78 pp 54-55

[Article by Albert Ducrocq]

[Text] For the first time since the beginning of the space age the Soviets have announced in advance the termination date of a flight in which only their own cosmonauts were involved.

This confirms our opinion that they now have their equipment--that of the station as well as that of the Soyuz--very well under control.

It was a rather new Soyuz which was at the disposition of Kovalenok and Ivanchenkov, the Soyuz 31 in this case, which Bykovskiy and Jahn left for them. And it is a Soyuz which Kovalenok and Ivanchenkov had the opportunity of testing on 7 September on the occasion of the maneuver whose result was to transfer the vehicle from the rear docking port to the forward docking port. Not only do the Soviet space cabins now appear to have attained the degree of reliability of the Americans but obviously the Soviets have in no way relaxed their safety standards.

Undoubtedly this situation inspires an observation. There are insistent rumors of the forthcoming utilization by the Soviets of a more spacious vehicle than the Soyuz, having from three to six places, and able to return in gliding flight, a vehicle which would be rather similar in its design and utilization to the one now under study by two French companies with a view toward eventual piloted flights which will one day come about with an evolved version of the Ariane [Ariadne]. Certainly the Soviets are readying a new piloted vehicle but we would be surprised if for all that they were to abandon, in the near future, the Soyuz which they have taken so much trouble to develop, and whose formula, consisting of lodging a crew in minimum space inside a cabin whose compactness assures its mechanical integrity, one may assume in any event will be retained.

Well Prepared Return

The return of Soyuz 31 appears not only to have been effected under excellent conditions but also to have been remarkably precise. A course correction had been made in due time, by using the Progress 4 as a locomotive, in order to give the trace of the orbit the optimum situation. This precision of the return was necessary for obvious medical reasons: the experts wanted to be able, as quickly as possible, to examine the cosmonauts after they had regained the earth's gravity. And in any event Kovalenok and Ivanchenkov had been instructed above all not to move on their own initiative after they landed. They were to wait until they were found and could be helped to come out from the Soyuz. The cabin door being located in the upper portion there is no question that in order to reach it they would have to raise themselves up within the cabin.

It was at 1105 hours, Universal Time, on 2 November, after a flight of 139 days, 14 hours, and 49 minutes, that Kovalenok and Ivanchenko put down on the steppes of Kazakh, 180 kilomters southeast of Djezkazgan. And immediately, examination of them reassured the experts. Of course, the two men were terribly tired. Regaining gravity was for them a terrible ordeal; if they had their way they would have walked on all fours. In addition, they had changed physically: their skin color, their silhouettes, and their features were no longer what they had been when they took off for space; extreme emaciation of their bodies, especially of their lower members, constrasted with the swelling and flattening of their faces.

To Remain in Bed

But that condition was fully in keeping with what the space physicians had predicted. And the first diagnosis was categorical: it is only a matter of a few weeks until the major after-effects of the flight would disappear and the cosmonauts would again begin living as earthlings, from which came the substance of the communique published by TASS at 1210 hours, only 75 minutes after the landing (which was announced at 1150 hours); it provided reassurance as to the health of the two men after the medical team had diagnosed that no irreversible difficulty was to be feared.

Kovalenok and Ivanchenkov are going to recover rapidly because a very strict procedure for their readaptation is being followed.

This must be emphasized. Something new in this flight is the great attention being paid to preparation of the cosmonauts for returning to terrestrial conditions. In the era of space cabins such preparation was non-existant; it would have been impossible to embark the equivalent of a Tchibis suit in a cockpit of minimum size. In retrospect we must admire the courage of the Americans, Lovel and Borman, remaining for 14 days aboard their Gemini 7 cabin. Already the observation of the latter of these astronauts has appeared significant. As a matter of fact Borman said, "On the whole one becomes well accustomed to weightlessness; the problems occur when one returns to earth." We must also admire the courage of the Soviets; Nikolayev and Sevast'yenov, who remained for nearly 18 days aboard the Soyuz 9; upon their return to earth they walked "bent like monkeys," Popovich told us. In that era of cabins preparation for returning commenced at the time of the return.

Things have indeed changed. With the facilities a station offers the preparation begins up in space. During the 96-day flight of Romanenko and Grechko preparation for the return while in orbit was spread over 5 days. This time it was extended to 10 days in space and 15 days after the return to earth. After being transported to Baykonur the cosmonauts were required to remain in bed and get up only gradually.

Why the choice of the reclined position? Very simply because gravity exerts minimum influence upon circulation of the blood when the body is horizontal. Thus, although not duplicated, the conditions of weightlessness are approached. In the epoch of the early space cabins the solution, after all, that imposed itself was to provide for the cosmonauts a position as close as possible to lying down; it was a matter of their systems enduring passage from 1 g to 6 g and more. When one returns to earth from space, passage from 0 g to 1 g must be endured; it is basically the same problem.

The cosmonauts' physician, Dr Robert Dyakonov would have liked Kovalenok and Ivanchenko to resume the standing position only after 4 to 7 days. But on 4 November the cosmonauts expressed their impatience. They asked that they be allowed to take their first walk in the park at their residence near Leinsk. In consideration of the rapidity of their recuperation their request in the end was satisfied.

Anti-g Suit

It will be remembered that for the re-adaptation of their cosmonauts the Russians developed trousers strangely reminiscent of the old "anti-g" suit designed in aeronautics to help pilots endure greater than normal gravity. During long sojourns in space there is in fact a redistribution of the blood, the system having become accustomed to no longer causing the valvules of the veins which provide for ascension of the blood from the lower members to function. Thus, after returning to earth, the problem is to avoid an accumulation of blood in the lower part of the body, as when greater than normal gravity is imposed.

By virtue of these considerations some observations are recalled to mind. In the heroic days of pre-astronautics--we mean the 1945-1957 period--lengthy discussions on the adaptation of man to a gravity different from his own took place.

But already, on the basis of experiments which had been performed in centrifuges, the experts concluded that the individual would undoubtedly adapt easily to lower than normal gravity, but only with great difficulty to higher than normal gravity, especially for a long duration, the situation of the higher beings, in this respect, being completely different from that of the fly which endures, the most humbly in the world, 600g. The opinion was that for an indefinite duration, the higher beings could not even endure a gravity of 1.4 g or only 1.3 g, which ruled out a priori man's sojourn upon the planets of the solar system where the gravity is greater than our own, especially on the surface of Jupiter; the problem at least arose at a time when it was still believed that there existed a solid ground on Jupiter. On the other side of the coin, the problems that might arise after a long sojourn upon the moon or Mars were cited--on returning to the earth's gravity.

Since that time the conclusions have changed hardly at all. Today space physicians are in agreement in recognizing that a reduced gravity is incomparably less troublesome than no gravity at all. Returning to earth after 4 or 5 months spent in weightlessness is, when all is said and one, perhaps as difficult as returning after a sojourn of a year or two on Mars, having gone there aboard a cosmic vehicle which would have a generator of an artificial gravity of 0.3g, this value being generally considered the minimum required to avoid the organic ill effects of weightlessness.

The Bottleneck

The Russians, with their operations aboard the Salyut 6, have achieved a two-fold breakthrough--both technical and medical.

Must it be assumed that they are going to be able to accelerate their program of long flights and that the 10-month mission about which we were talking not very long ago may take place sooner than foreseen?

It is not certain.

As a matter of fact it will be remembered that this year's flights were thoroughly prepared, thanks to research of various kinds, which combined theoretical studies with sojourns of long duration in the isolation chambers of the Institute of Space Biology in Moscow. Moreover, the Soviets were able to profit greatly from the lessons learned during the American flight of 84 days which ended in February 1974. In 1975 the Russian physicians gave the green light for a 3-month flight of cosmonauts, a flight which could not take place--it was achieved only in 1978--not for medical reasons, but essentially for technical reasons, namely, deficiencies in the equipment which did not have all the advantages provided this year by the Salyut 6. In other words, in the medical chronology, it will be remembered, there has been an advance in the space of 3 years from 3 months to 4-1/2 months.

However, from all available evidence it appears that the Russian do not intend to proceed with the 5-month flight. Their statement alludes to the preparation for a 6-month flight, which could represent the next step, but no one can say when it will be accomplished.

It must be remembered that today the bottleneck in lengthening the duration of flight is no longer at the technical level--with the Salyut 6 and the Progress vehicles which supply it nothing should materially prevent the Russians from leaving their cosmonauts in space for 1 year but medical considerations. And for this reason the date at which the Russians will be able to undertake accomplishment of this 6-month flight about which they are already dreaming will be indicative of the rate at which it can be hoped that both the problem of adapting the human system to weightlessness for a long duration and that of subsequent readaptation to the earth's gravity will be resolved.

Planetary Voyages

An observation by Leonov certainly merits attention. The first man to walk in space, who has become a general--of whose recent promotion at the City of the Stars we have learned; he is now its deputy director--states that the exploit of Kovalenok and Ivanchenkov opens the way to planetary flights.

For some 20 years we have become used to hearing the Soviets declare that everything presages everything and we know that in their terminology the world "soon" can have a highly elastic meaning. It seems to us, nevertheless, that considering Leonov's new functions his words cannot be taken lightly.

Achievement of piloted flights in the solar system in fact requires solution of two very distainct categories of problems, some technical and the others "medical-human."

But even though unresolved at the present time the first category can be very quickly resolved, especially if a simple voyage in an equitemporal orbit is contemplated (a trip in a solar orbit permitting return to earth at a time planned in advance); some modes appear not to be costly in energy. On the other hand, it is the "medical-human" problems which are complex, these problems including not only the feasibility of men remaining in space for a certain time but the obligation to remain there until the end of the mission.

Kovalenok and Ivanchenkov, in the course of their flight, traveled some 92,803,000 kilometers which indeed is equivalent to a potential small trip in the solar system. But they had the option of returning at any moment: the flight was open. Departing with the knowledge that one must obligatorily travel 92,803,000 kilometers before having the right to return is quite another matter. It requires that there be, on the subject of medical-human problems, a mastery of the situation comparable to that now possessed at the technical level, and that is far away.

Nevertheless all things let it be believed that the Soviets are going to continue to devote maximum effort and that the objective may be attained in a reasonable time: Piloted flight to Mars before the year 2000 appears to us to be a prospect which today must be taken more seriously than ever.

[Photo caption] The two new space record holders, Vladimir Kovalenko (left) and Aleksandr Ivanchenko (right) returned to earth safe and sound on 2 November 1978 after a flight of 140 days, which is the longest space flight accomplished up to now by human beings.

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PHYSICS

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NUMERICAL ANALYSIS OF CHARACTERISTICS OF A GAS DYNAMICAL LASER WITH SELECTIVE THERMAL EXCITATION AND MIXING IN THE SUPERSONIC FLOW

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 5 No 11, 1978 pp 2337-2341 manuscript received 10 Oct 77

[Article by O.V. Achasov, R.I. Soloukhin and N.A. Fomin, Belorussian SSR Academy of Sciences Institute of Heat and Mass Exchange imeni A.V. Lykov, Minsk]

[Text] Based on a simple mathematical model, a numerical analysis is made of the characteristics of a gas dynamical laser (GDL) with selective excitation and mixing in the supersonic flow. An analysis is made of the dependence of characteristics of this GDL (gain and power output) on different parameters. The calculated dependence obtained for the gain on temperature agrees with experimental data with a degree of accuracy which is not too bad for preliminary estimates. The results of estimates of the unit power output in a GDL employing mixing make it possible to explain the experimentally observed tendency toward an increase in the optimal braking temperature with an increase in the concentration of helium in the injected mixture.

In spite of the large number of estimates for gas dynamical lasers (GDL's) operating in the mode of cooling of a preblended mixture of molecular gases, at the present time there are practically no calculations modeling the operation of a GDL with selective excitation and mixing in the supersonic flow. At the same time GDL's with mixing have record power output ratings and have considerably higher efficiency in converting heat energy into coherent radiation energy.

Numerical estimates in [1] show that the chilling efficiency of vibrational energy in a nozzle with mixing is approximately 1.5 times higher than in an ordinary nozzle. A number of additional advantages of GDL's utilizing a mixing system, as well as detailed results of experimental research on GDL's of this type, are given in [2]. The lack of estimates mentioned is explained by the considerable complication of the task of numerically modeling the characteristics of a GDL when going to a system with selective excitation and mixing in the supersonic flow. This complication involves the need to solve a system of relaxation equations in a two-dimensional field of variation of gas dynamical parameters, and the determination of these parameters while taking into account the actual processes originating in the supersonic mixing zone (shock waves, rarefaction waves, regions of boundary layer separation, etc.) involves serious difficulties even for the simplest mixing systems. Furthermore, the output characteristics of a GDL with selective excitation and mixing will be governed by a collection of many parameters: the pressure and braking temperature of the nitrogen, the pressure and composition of the injected mixture, the mixing point, the geometry of the nozzle in front of and behind the injection plane, the parameters of the cavity, etc. In this paper an attempt is made to estimate (for the present, without optimizing) the characteristics of the inverse medium of a GDL with selective thermal excitation and mixing, with the following simplifying assumptions.

1. The mixing is regarded as instantaneous and takes place in the plane of injection of a flow of CO_2-He without distortion of the gas dynamical pattern of the main stream (i.e., shock waves and the like do not originate in the flow). Furthermore, all changes in gas dynamical parameters concentrated in the injection plane are calculated from the mass, impulse and enthalpy balance of the main and secondary flows. In case of a nonlinear dependence of the enthalpy on the temperature of the gas, the system of mass, impulse and enthalpy conservation equations does not have an analytical solution and reduces to a transcendental equation, which has been solved numerically.

2. Not considered in this paper are losses of vibrational energy during the relaxation of pure nitrogen in front of the point where the CO_2-He mixture is blended. This simplification makes it possible to eliminate integration of the system of differential equations when crossing a particular point in the vicinity of the nozzle's critical cross section.

Check calculations made by the ascertainment method have shown that losses of vibrational energy on account of relaxation during cooling of the pure nitrogen in the supersonic nozzle (model of a harmonic oscillator) do not exceed one to three percent of the stored vibrational energy. More precise estimates taking into account the anharmonicity of vibrations of nitrogen, made in [3], showed that these losses can be somewhat higher, but in this case they do not exceed four to seven percent for the entire range of characteristic values of parameters of GDL's with selective excitation and mixing.

3. The efficiency of the cavity in this study was considered constant and was assumed to equal 0.8. This value is the maximum experimental value of the cavity's efficiency (from the data of survey [4]).

4. The system of vibrational relaxation equations for a CO_2-N_2-He mixture, as well as the key equations needed to estimate the gain, were taken from [5,6]. Calculations were made for the nozzle geometry and mixing unit used in the experiments in [2,7] ("rapidly" expanding nozzle with a knife edge in the critical cross section).

The distributions shown in fig 1 for the translational and vibrational temperatures along the nozzle for typical conditions of a GDL with selective excitation and mixing illustrate the numerical solution system described above. As is obvious from this figure, during injection of a mixture with a high helium content, at the injection plane is observed considerable additional cooling, caused by the redistribution of enthalpies between the hot nitrogen and the cold injected gas. For the conditions shown in fig 1a the intensity of additional cooling reaches 800°K.

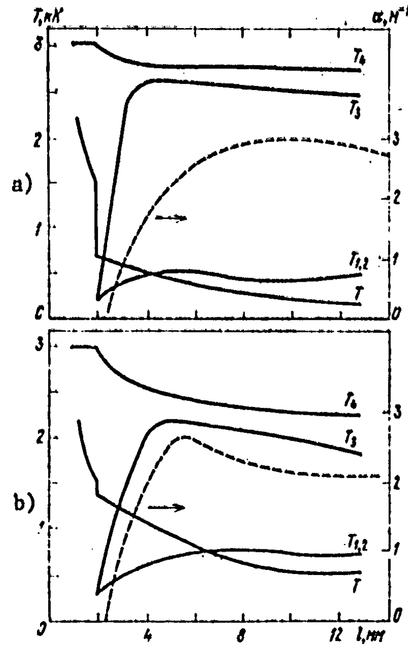

Figure 1. Distribution of Translational and Vibrational Temperatures and Gain Along the Nozzle. Temperature and Pressure in Prechamber 3 kK and 10 atm: a) injected mixture of CO_2+9He, injection pressure 9 atm, composition of gas after mixing: 0.055 CO_2 + 0.452 N_2 + 0.493 He; b) injected mixture of CO_2+He, injection pressure 5 atm, composition of gas after mixing: 0.227 CO_2 + 0.546 N_2 + 0.227 He.

In the course of further expansion, subsequent gas cooling takes place, with an effective adiabat figure appropriate to the resulting gas mixture. Considerably less cooling can be expected when injecting a gas with a relatively moderate concentration of helium in the mixture (fig 1b). Cooling in the course of further expansion in this case also occurs more slowly because of lowering of the mixture's adiabat figure. Therefore, the final temperature of the gas at the cavity's inlet with a degree of expansion of $A/A^* = 30$ (fig 1b) turns out to be fairly high (approximately higher than 500°K), which results both in considerable settlement of the ground laser level and in high losses of frozen vibrational energy at the higher laser level.

As calculations have shown, when injecting pure carbon dioxide into the supersonic flow, at the injection plane there occurs a rise in the translational temperature of the gas as the result of predominance of the temperature restoration effect during braking of the flow. In this case inverse population density and positive gain should be expected only with relatively moderate braking temperatures (approximately less than 2 kK) or with considerable degrees of expansion of the gas.

It is obvious from fig 1 that, in the flow beyond the injection plane, as the result of rapid resonance transmission of excitation from N_2 (v = 1) to the 001 level of the CO_2 molecule, there occurs a rapid rise in the temperature of asymmetric vibrations, T_3, of molecules of carbon dioxide. The temperature of symmetric vibrations (it is assumed that flexural and symmetric vibrations of molecules of CO_2 have a common temperature: $T_1 = T_2 = T_{1,2}$) first also rises to values corresponding to the translational temperature, and then "freezes" at values higher than the value of T by a factor of 1.2 to 1.5. As demonstrated by an analysis of calculation results, the approximately constant value of temperature $T_{1,2}$ in this region is caused by equalizing of the velocities of two processes: by a reduction in $T_{1,2}$ because of VT-relaxation, and by an increase in $T_{1,2}$ because of exchange of energy with the asymmetric vibration mode.

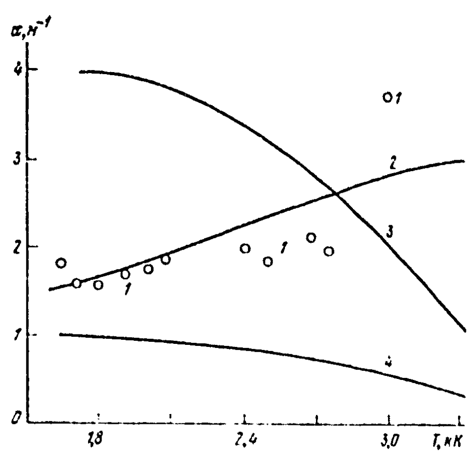

Figure 2. Experimental Values from [7] and Calculated Dependences of Gain on Braking Temperature with Pressure in the Forechamber Equal to 10 atm: 1,2--injection conditions same as in fig 1a; 3,4--injected mixture of CO_2+He, injection pressure 5 atm (3) and 1 atm (4)

Dependences of the gain formed in the flow on the braking temperature are shown in fig 2. Plotted on the same figure are experimental data on the dependence of the gain on the temperature in a GDL with selective thermal excitation and mixing in the supersonic flow [7]. As is obvious from fig 2, when $T \lesssim 2$ kK there is good agreement between the experimental and calculated dependences, and when $T \gtrsim 2.5$ kK the difference between measured and calculated values of the gain is about 20 percent, which is totally acceptable for preliminary estimates, since the accuracy of kinetic calculations because of the indeterminacy of relaxation constants alone [8] is 30 percent. But it must be mentioned that the influence of the indeterminacy of kinetic calculations in a GDL employing mixing is substantially less, since vibrational relaxation processes are concentrated in this case in the low-temperature half of the nozzle (the supersonic flow), and the data on vibrational relaxation constants when $T \lesssim 1$ kK are more complete.

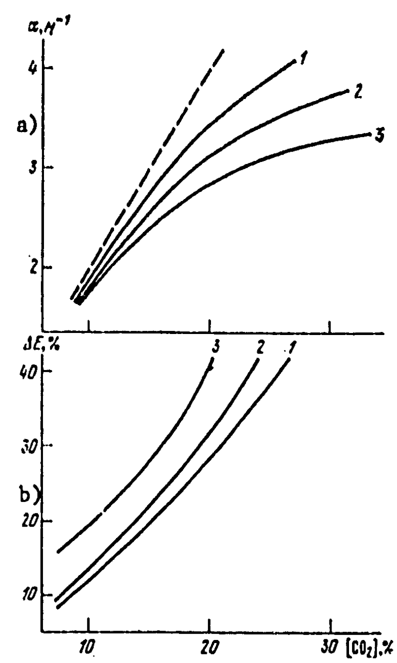

Figure 3. Dependence of Gain (a) and Losses of Vibrational Energy in the Flow Beyond the Mixing Point (b) on the Percentage Content of Carbon Dioxide in the Resulting Mixture: Temperature in Forechamber 2 kK, injected mixture CO_2+He, injection pressure 1 to 7 atm; nitrogen pressure in forechamber 10 (1), 20 (2) and 50 (3) atm; the dotted line indicates the dependence without taking vibrational relaxation into account.

In addition, analysis of the data given in fig 2 shows that the optimal composition of the injected mixture depends heavily on the temperature: In low-temperature GDL's employing mixing ($T \sim 2$ kK), high gain is achieved when injecting a mixture with a relatively moderate helium content, whereas with a rise in temperature it is necessary to increase the helium content. It was noted above that here there is an increase in the intensity of cooling at the injection plane, as well as in the mixture's resulting adiabat figure. This trend is qualitatively in good agreement with the results of experimental investigations of the characteristics of GDL's with selective thermal excitation and mixing with different ratios of CO_2 and helium in the injected mixture [7].

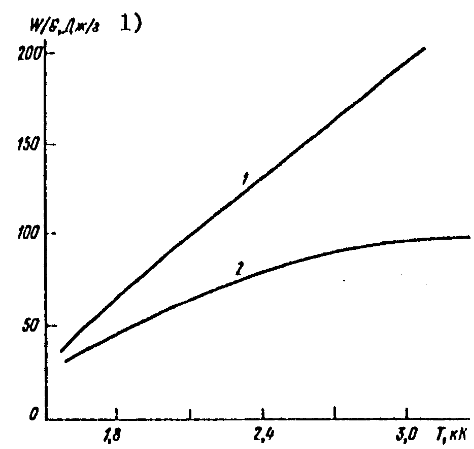

Figure 4. Dependence of Unit Power Output in a GDL with Selective Excitation and Mixing on Nitrogen Braking Temperature Taking into Account the Vibrational Energy of All (1) and of Only the Ground (2) Vibrational Levels; Conditions Same as in fig 1a

Key:

1. W/G, J/g

The data given in fig 3 make it possible to select the optimal content of carbon dioxide in the resulting mixture for a specific unit. With an increase in the content of CO_2 the GDL's gain increases (fig 3a), but here there is an increase in losses of vibrational energy in the flow beyond the mixing plane (fig 3b) (losses refer to the total supply of frozen vibrational energy, taking the quantum yield into account). Therefore, the optimal concentration of CO_2 will be different for units with different cross dimensions: With not too great a length of the optical path the total gain per operation will be not too great and can prove to be comparable with losses in reflecting surfaces and because of resonance absorption in the flow. Here it is necessary to increase the concentration of CO_2 for the purpose of increasing the gain, in spite of the increase in vibrational energy losses.

The data given in fig 4 illustrate the dependence of calculated values of power output in a GDL employing mixing on the braking temperature of nitrogen. Earlier in [2] there was observed an increase in the thermodynamic efficiency of the conversion of thermal energy into coherent radiation energy with a rise in temperature. As demonstrated by the results of calculations shown in fig 4, with a rise in the braking temperature of nitrogen from 2 to 3 kK, the unit power ouput in a GDL with selective thermal excitation and mixing is increased more than twofold and reaches a value of about 200 J/g. Taking into account the energy of just the ground vibrational level of a molecule of nitrogen, this figure is lowered approximately twofold.

In summary, let us say that in this paper, based on a simple computation system, a numerical analysis has been made of dependences of the characteristics of a GDL with selective thermal excitation and mixing in the supersonic flow, on various parameters. Furthermore, the calculated dependence of the gain on temperature agrees with the experimental data with a degree of accuracy which is not too bad for preliminary estimates.

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8831
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PHYSICS

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INVESTIGATION OF THE GENERATION PROPERTIES OF PHOSPHATE GLASSES IN THE PULSE REPETITION PUMPING MODE

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[Article by N.Ye. Alekseyev, V.V. Gruzdev, A.A. Izyneyev, Yu.L. Kopylov, V.B. Kravchenko, Yu.S. Milyavskiy, Yu.N. Mikhaylov, S.P. Rozman and A.M. Fisher, USSR Academy of Sciences Institute of Radioelectronics, Moscow]

[Text] A study is made of the influence of a thermal lens originating in the glass active element on the operation of a laser in the pulse repetition mode. It is demonstrated that the generation power and the strength of the thermal lens vary in a similar manner with a change in temperature. Low thermal lens strengths are achieved in glasses with low values of thermo-optical constants P and Q . The temperature dependence of the strength of the thermal lens is reduced with a reduction in the derivative of the value of P in terms of temperature. It is demonstrated that with not too high pumping pulse repetition rates glass lasers can have power characteristics close to the characteristics of yttrium-aluminum garnet crystal lasers.

The purpose of this paper was to make a study of the properties of certain phosphate glasses in the pulse repetition mode with a high mean pumping power. Of course, in the operation of a solid-state laser in the pulse repetition or continuous mode, with cooling of the side surface in the active element (AE) a thermal lens originates, whose strength depends in the best approximation on the thermo-optical characteristics of the glass, P and Q [1], and on the temperature drop in the AE, i.e., on the mean pumping power (cf., e.g., [2]). The appearance of a thermal lens results in distortion of the cavity, which is especially strongly pronounced in the operation of pulsed lasers with optical-mechanical Q switching. With an increase in pumping power the efficiency usually first increases, and then is lowered as a result of an increase in the optical strength of the thermal lens.

The efficiency of silicate glass lasers is 0.025 to 0.5 percent, the pulse energy is 0.001 to 2.5 J, and the repetition rate is 1 to 85 Hz [1-6]. For phosphate glasses, which have better thermo-optical properties, the efficiency in the free generation mode for a cylindrical AE equals 0.03 [7] and 1 [8] percent with respective rates of 50 and 5 Hz, and in the Q switching mode, for a rectangular AE, approximately 0.2 percent [9] with a rate of 2 to 5 Hz. Glass lasers thus have relatively not too high efficiency.

The formation of a thermal lens in an AE made of silicate glass is the key factor limiting the generation power in the pulse repetition mode: With a certain strength of the thermal lens the cavity leaves the stability region, and generation is cut off prior to reaching of the AE's thermal breakdown threshold [10,11].

With the parabolic temperature distribution established in a "long" cylindrical AE under conditions of uniform heat release and intense cooling of the side surface, the difference in the optical path between the center of the AE and any point for rays with radial (r) and tangential (θ) polarization in the best approximation is given by the equation [2]:

$$\Delta P_{r,\theta}(0) - \Delta P_{r,\theta}(r) = L\,[P \pm (Q/2)]\Delta T\,(r^2/c^2),$$

where r is the instantaneous radius; c is the radius of the AE; ΔT is the temperature drop between the center and edge of the AE; and L is the length of the AE. This equation does not take into account the temperature dependence of thermo-optical characteristics P and Q and is, generally speaking, inaccurate, since it permits total compensation of the thermal lens for one polarization with any value of the temperature drop in the case when $P \pm Q/2 = 0$.

Actually, the thermo-optical properties of glass vary rather strongly with temperature [12,13]. Taking this dependence partially into account gives this expression for the difference in the optical path [14]:

$$\Delta P_{r\theta}(0) - \Delta P_{r\theta}(r) = L\Delta T\left\{\left[P_0 \pm \frac{Q_0}{2} + \Theta(T + 2\Delta T)\right]\frac{r^2}{c^2} - \Theta\Delta T\frac{r^4}{c^4}\right\}.$$

Here the values of P_0 and Q_0 are taken at a specific temperature of T_0 ; T is the temperature of the side surface of the AE read from T_0 ; $\Theta = dP/dT$ is the temperature derivative of thermo-optical characteristic P . The analogous temperature derivative for Q is an order of magnitude lower than Θ [13] and in deriving this equation was taken as equal to zero.

It is obvious from this equation that the magnitude of optical distortions in the AE depends substantially on the temperature drop and thermo-optical constants at a given temperature and on their temperature dependence. The difference between glasses with different thermo-optical properties should be more distinctly manifest with greater temperature gradients. In recent years glasses have been developed with low values of P_0 and Q_0 , in particular, phosphate glasses. Their disadvantage is relatively low thermostability. For example, cylindrical AE's measuring 10 X 130 mm made of GLS-22 glass endure a pumping power in the pulse repetition mode of only up to 300 W [8].

Methods of hardening AE's developed in recent times have made it possible to raise the ultimate endurance of AE's made of phosphate glasses two- to threefold, with regard to pumping power [8,15]. We have made studies with AE's measuring 8 X 100 mm made of phosphate glasses, which endured a pumping power of 250 and 500 W. A monoblock light source was used, made of quartz glass with circulation cooling, the pumping rate equaled 5 to 15 l/min, and the cooling fluid absorbed UV pumping radiation shorter than 410 nm. For Q switching was employed an optical-mechanical shutter with a rotational velocity of (21.5 to 43)$\cdot 10^3$ r.p.m. The temperature of the AE was measured with reference to its elongation with a known thermal expansion coefficient, as well as by means of a thin thermocouple inserted into the center of the AE. In fig 1 is shown the dependence of the temperature drop on pumping power for AE's made of phosphate glasses GLS-22 and LGS-I and the alkali phosphate glass LGS-M. In table 1 are given thermo-optical characteristics P and Q of these glasses, where it was assumed that the temperature coefficient of P equals the temperature coefficient of thermo-optical characteristic W [13,14]. The values of P_0, Q_0, and Θ for GLS-1 (silicate) and GLS-22 glass were taken from [14], the induced radiation cross sections, σ, for these glasses from [16], and the values for LGS-I and LGS-M glass were measured by us.

Table 1.

1) Марка стекла	$\sigma \cdot 10^{20}$, $см^2$	$P_0 \cdot 10^7$, K^{-1}	$Q_0 \cdot 10^7$, K^{-1}	$\Theta \cdot 10^7$, K^{-1}
2) ГЛС-1	2,5	32	6	0,23
3) ГЛС-22	3,4	—2	4	0,14
4) ЛГС-И	3,0	—4	5	0,14
5) ЛГС-М	3,9	—6	5,5	0,09

Key:

1. Brand of glass
2. GLS-1
3. GLS-22
4. LGS-I
5. LGS-M

In fig 2 is shown the dependence of free generation power on the pumping pulse rate (the energy in a single pulse is fixed and equals 100 J). It is obvious that above a certain boundary pumping power a rise in the laser's output power is slowed down. The value of this boundary pumping power depends on thermo-optical characteristics P_0 and Q_0, and the slope of the $W_{vykh}(W_n)$ [output power (pumping power)] curve depends also on the temperature dependence of thermo-optical characteristics.

In fig 3 is shown the experimentally determined change in focal length of the thermal lens formed near the center of the active element, and in fig 4 the change in generating power with temperature for a pumping power of 500 W.

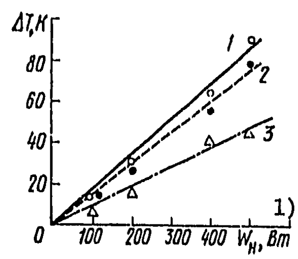

Figure 1. Dependence of Temperature Drop in an AE on Pumping Power for LGS-I (1), LGS-M (2) and GLS-22 (3) Glass

Key:
1. W_n, W

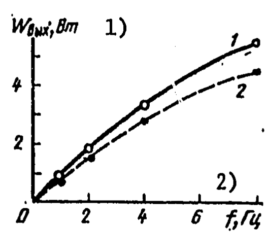

Figure 2. Dependence of Generation Energy in a Pulse on Repetition Rate for LGS-I (1) and LGS-M (2) Glass (R = 50 percent)

Key:
1. W_{vykh}, W 2. f, Hz

It is obvious that the strength of the thermal lens and the generation power vary similarly for phosphate glasses with low values of P_0 and Q_0. Furthermore, the lower the value of Θ, the more gently sloping are the curves for the dependence of the strength of the thermal lens and of the generation power on temperature. A quantitative discussion of this dependence is difficult now, since it is necessary to take into account a number of secondary phenomena, such as the misadjustment of the cavity because of the difference in the thermal expansion coefficients of the AE and cavity elements, additional stresses in the AE because of the change in the security of the mounting with temperature, etc. Let us state only that LGS-M glass has advantages over the other glasses from the viewpoint of operation over a wide temperature range. In the free generation mode, for example, an AE measuring 8 mm in diameter by 100 mm made of LGS-I glass, without optimization of the system (selecting mirrors and the ratio of diameters of the AE and pumping tube, etc.), produces 1 J of power when pumping with a 70 J, 10 Hz pulse.

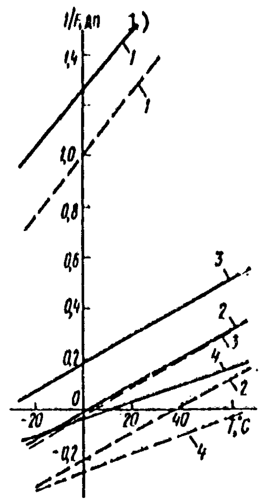

Figure 3. Change, with Temperature, of Focal Length of a Thermal Lens Near the Center of the AE for Radial (Solid Line) and Tangential (Dotted Line) Polarization in GLS-1 (1), GLS-22 (2), LGS-I (3) and LGS-M (4) Glass

Key:
1. Fraction of percentage

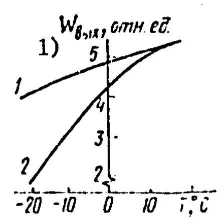

Figure 4. Change in Generation Power in a Pulse Versus Temperature for LGS-M (1) and GLS-22 (2) Glass

Key:
1. W_{vykh}, relative units

In fig 5 is shown the generation power at room temperature in the Q switching mode for GLS-1 and LGS-I glass. The output generation power equals, respectively, 3.5 W when pumping at 500 W for LGS-I glass and 0.8 W when pumping at 420 W for GLS-1 glass, i.e., LGS-I glass in the same system makes possible several times greater generation power. Optimization of the system's elements has made it possible to obtain in the Q switching mode, with f = 10 Hz, when using an AE made of LGS-I glass, a pulse power of 0.6 J with 40 J pumping. The amount of angular divergence in terms of the 0.8 level from the total power has equaled 22'. These results speak for the sufficiently high efficiency of phosphate glasses with elevated pulse repetition rates and for the promise of their application in pulse repetition lasers.

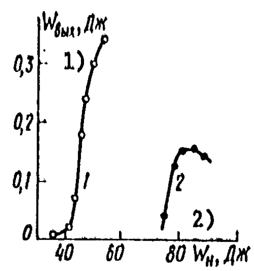

Figure 5. Generation Power in the Q Switching Mode for LGS-I (1) and GLS-1 (2) Glass with Repetition Rates of 10 and 5 Hz, Respectively (R = 63 percent)

Key:

1. W_{vykh}, J
2. W_n, J

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PHYSICS

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A COMPARATIVE INVESTIGATION OF PULSED HF AND $DF-CO_2$ CHEMICAL LASERS

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 5, No 11, 1978 pp 2436-2444

[Article by V. Ya. Agroskin, G. K. Vasil'yev, V. I. Kir'yanov and V. L. Tal'roze, Institute of Chemical Physics, USSR Academy of Sciences, submitted to the editorial board 27 November 1977]

[Text] An experimental study was made of the basic characteristics of pulsed, photoinitiated HF and $DF-CO_2$ lasers using a single equipment set-up in a wide range of variation of the initial conditions: pressure, initiation, temperature and mixture composition. A comparison was made of the characteristics found and the possibility of technical optimization of the functioning of these lasers was analyzed.

Lasers based on a reaction between fluorine and hydrogen or deuterium occupy a distinctive position among pulsed, photoinitiated chemical lasers because they have the highest specific energy densities. The working molecules in them are either the immediate products of the reaction--HF or DF molecules (HF and DF lasers), or molecules of CO_2 to which oscillation excitation energy is transferred from DF molecules ($DF-CO_2$ laser). The study of these lasers has been the subject of many experimental and theoretical works (see [1-5], for example), both monographic and review-type. There is, at the same time, a lack of studies in which the characteristics of HF and $DF-CO_2$ lasers were compared under the same experimental conditions.

The main purpose of the present work was the comparative investigation of these lasers using one and the same set-up while varying the initial conditions and mixture composition around the optimum. Additionally, with the aim of revealing the connection between the characteristics of laser action and the kinetics of the chemical reaction we investigated the photoinitiated reaction by the method of optical probing [6] of the fluorine molecule concentration in the mixture. Finally, we thought it necessary to offer a number of characteristics of the lasers which the literature hasn't covered, as far as we know. We would like to point out that we have characterized initiation by the level of dissociation of the fluorine molecules.

The Procedure

The equipment for the experiment was the same as that described in [7, 8]. A pulsed gas-discharge lamp of up to 20 kJ electrical energy was used for initiation of the chemical reaction. The reactor was either a quartz tube 3 cm in diameter and some 90 cm long with an external coaxial lamp, or a stainless steel tube 4.5 cm in diameter and 70 cm long with a tubular or coaxial lamp inside it. Mixing of the gases was done during their admission into the reactor in special mixers at room temperature. The admission rate was 0.4-0.8 mmole/s with dosing accuracy of mixture components at $\sim$10%.

The laser resonator was made up of a flat metal mirror and a semitransparent plate out of Al_2O_3 or BaF_2 (HF laser) and KRS-6 (TlCl-TlBr) or ZnSe ($DF-CO_2$ laser). The level of dissociation of the F_2 molecules throughout the initiation impulse was determined with an accuracy of $\sim$ 30% by two methods [3] independently for each reactor. The shape of the initiating pulse was recorded by a photomultiplier, and the laser action pulse by a detector using a p-germanium crystal operating at room temperature [9]. The time resolution of these instruments was not worse than 0.1 μs. The laser action spectrum was recorded by a Perkin-Elmer Company monochromator with a slit spectral width of 0.7 cm^{-1}.

To probe the concentration of fluorine in the mixture at a wavelength of 334 nm we used a high pressure mercury vapor lamp, monochromator and photomultiplier. In the experiments we varied the initial composition of the mixture, the level of dissociation of F_2 molecules during the initiating pulse α=0-5%, the overall initial pressure of the mixture p_0=0-2 atm and the initial temperature T_0=200-450 K. The initial pressure and temperature were established with an accuracy not worse than 2% and 4%, respectively. The energy of laser action was measured by calorimeter to within 10-15% accuracy. The purity of the gases used was: H_2-99.5%, D_2-99.5%, $F_2 \gtrsim$ 98%, O_2-99.4%, CO_2-99%, He-99.8%.

Experimental Results and Discussion

As was demonstrated earlier [3, 10], the photoinitiated reaction of $H_2(D_2)$ with F_2 proceeds either with a cessation at low intensities of chemical conversion, or to total burn-up (explosive condition), with the transition from one condition to the other bearing a critical character, i.e., it happens with a small variation of any parameter (α, p_0, mixture composition). The investigations showed that laser action in a $DF-CO_2$ laser takes place only under the explosive chemical reaction condition.

Figure 1a and 1b illustrate the position of the lasing pulse of a $DF-CO_2$ laser and the kinetics of consumption of F_2 molecules relative to the photoinitiation pulse for a mixture of 5%D_2-10%F_2-25%CO_2-0.5%O_2-59.5% He at p_0=1 atm, $T_0 \approx$ 300 K, α= 0.45% in a reactor 50 cm long. The relative sensitivity of the method for recording the concentration of fluorine molecules $\Delta [F_2]/[F_2]_0$ amounted to about 5% which, in terms of HF molecule concentration, gives a value of $2.5 \cdot 10^{17} cm^{-3} \cdot atm^{-1}$.

$$\frac{\Delta [F_2]}{[F_2]_0} = \frac{\Delta J}{(J_1 + \Delta J) \ln (J_0/(J_1 + \Delta J))},$$

where ΔJ is the minimum signal change distinguishable against the noise background of the probing beam, the photomultiplier and the thickness of the oscillograph trace.

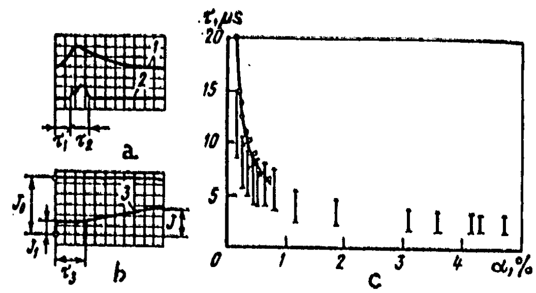


Figure 1. Oscillograms of initiation (1) and laser action (2) pulses, and the kinetics of fluorine molecule consumption (3) in a $DF-CO_2$ laser (a, b; time base 2.5 us/division), and also the duration (vertical segments) and position of the laser action pulse relative to start of initiation and the "induction period" of the chemical reaction (o) in relation to the overall level of fluorine molecule dissociation in the mixture (c).

It is seen from Figure 1b that the reaction has an "induction period" τ_3 [10], delimited by the sensitivity of the procedure, and laser action defined by the period τ_2 (at a level of 0.1 of maximum amplitude) with lag τ_1 takes place for the given value of c at a relatively low intensity of mixture burn-up and correspondingly low warm-up ($\Delta T < 100$ k). The quantity J_0 corresponds to the amplitude of the probe light in the absence of F_2; J_1 and J correspond to the amplitudes at onset of and during chemical reaction.

Figure 1c (see also Figure 2c) shows the relationships of τ_1, τ_2 and τ_3 to α for a mixture of $5\%D_2-15\%F_2-25\%CO_2-1\%O_2-54\%$ He in a reactor 90 cm long at $p_0=1$ atm, $T_0=300$ K. It is seen that in the case of a weak initiation ($\alpha \lesssim 0.7\%$) the main part of the lasing energy is given off at an earlier stage of the chemical reaction, i.e., at a relatively moderate temperature, not exceeding 400-450 K. As we know (see [11], for example), in an HF laser, in the same α range, laser action continues up to substantially higher intensities of mixture burn-up and, consequently, higher temperatures ($\sim$1000 K). It is to be noted that in a $DF-CO_2$ laser, when initiation is powerful enough, the fluorine consumption observed on longer time bases ($\gtrsim$10 μs/division) in the course of the chemical reaction exceeds the initial deuterium concentration in the mixture; evidently, this is connected with supplemental F_2 consumption in photochemical reaction with CO_2 [12]. Investigations have shown that supplemental fluorine consumption accelerates with initiation build-up.

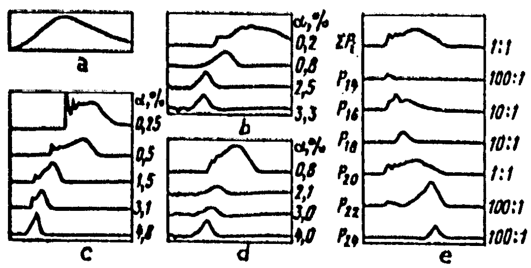


Figure 2. Shape and relative position of pulses of initiation (a) and laser action of a DF-CO_2 laser in mixtures of 5%D_2-15%F_2-CO_2-O_2-He, containing 10%CO_2 and 1%O_2 (b), 25%CO_2 and 1%O_2 (c), 79.4%CO_2 and 0.6%O_2 (d), with varied initiation; oscillograms of the spectrum (e) for mixture (c) at $\alpha \approx 0.3\%$ (~ 3 μs delay of triggering; intensity scale is shown on right side). Time base is everywhere 12 μs; p_o=1 atm; $T_o \approx$ 300 K.

Figure 2b-d shows the shape and position of the laser action pulse of the DF-CO_2 laser relative to the initiating pulse (Figure 2a) for various concentrations of CO_2 molecules in the mixture at p_o=1 atm, $T_o \approx$ 300 K and α = 0.2-5%. Variation of the initial CO_2 concentration in the mixture was compensated by a corresponding variation of the He concentration. It can be seen from Figure 2 (see also Figure 1c) that as α rises the periods τ_1 and τ_2 diminish, whereby the lasing condition becomes quasistable.

Spectral investigations of the DF-CO_2 laser have shown that there is in the emission spectrum only the P-phase of rotation transitions of the 00^01-10^01 oscillation band. The R-phase was not detected even with an increase in sensitivity to 10^5 times relative to the P-phase. As can be seen from the spectrum oscillograms in Figure 2e, lasing starts first at transitions P14, P16, P18 and P20 with P22 and P24 included later on in the lasing process. The table which follows shows the fractions of the laser action energy on all observed lines in the range α = 0.2-1.0%.

Transition	Energy Fraction, %	Transition	Energy Fraction, %
P14	0 - 1	P20	70 - 90
P16	4 - 12	P22	2 - 3
P18	4 - 12	P24	0 - 1

It is to be noted that in the case of initiation close to the threshold ($\alpha \approx 0.15\%$) the fraction of transition P20 may vary over a wide range (10 - 90%). As can be seen from the data obtained, lasing takes place mainly from rotational levels J=15, 17, 19, the population of which, with balanced rotational distribution, is maximal at temperatures of 300-400 K. This is in good agreement with the results obtained during concomitant investigation of the processes of laser action and chemical kinetics (see Figure 1). We want to point out that in [13], under heavy helium dilution of the mixture and at low pressure, laser action likewise occurred primarily at the P16, P18 and P20 transitions. In contrast to the $DF-CO_2$ laser, the HF laser spectrum is known [11, 14] to exhibit several dozen lines.

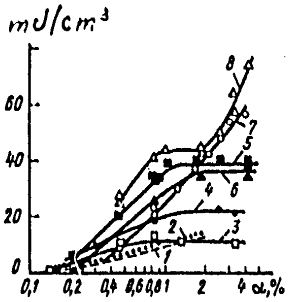


Figure 3. Relationships of specific energy yield to initiation for an HF laser using mixtures $3.7\%H_2-11.1\%F_2-2.2\%O_2-83\%He$ (1), and $14.5\%H_2-43.5\%F_2-8.5\%O_2-33.5\%He$ (2), and for a $DF-CO_2$ laser using a mixture of $5\%D_2$, $15\%F_2$ and He, plus $5\%CO_2$ and $1.5\%O_2$ (3); $10\%CO_2$ and $1\%O_2$ (4); $25\%CO_2$ and $1\%O_2$ (5); 45% CO_2 and $0.8\%O_2$ (6); $79.4\%CO_2$ and $0.6\%O_2$ (7); and also, using a mixture of $10\%D_2-30\%F_2-59\%CO_2-1\%O_2$ (8).

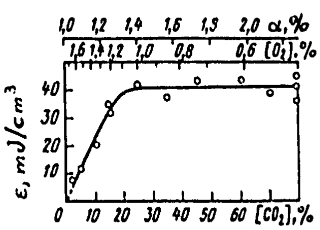


Figure 4. Relationship of energy yield of a $DF-CO_2$ laser to CO_2 concentration in a mixture of 5% D_2 - 15% F_2 - CO_2 - O_2 - He in the case of unchanging chemical reaction conditions.

Simultaneously with the shape of the laser action pulses of the $DF-CO_2$ laser, we investigated the relationship of the specific energy yield to initiation for mixtures with a varied CO_2 content at p_0=1 atm, $T_0 \approx 300$ K. From the results, which are shown in Figure 3, it can be seen that all the relationships have a threshold and, for mixtures with helium, a tendency toward saturation as well. An analogous relationship was found for a diluted mixture at p_0=0.3 atm, for example, in [15]. Without helium in the mixture there is no saturation of energy density even up to $\alpha \approx 5\%$. The maximum chemical efficiency achieved hereby is 5%. Particular attention should be paid to the nature of the $\varepsilon(\alpha)$ relationship for the mixture 10% D_2-30% F_2-59% CO_2-1% O_2 for which, after an intermediate plateau in the interval $\alpha = 1$-2%, the energy density begins to rise again with further increase of α. Maximum energy density for this mixture was 0.07 J/cm^3 (3.5% chemical efficiency), which is close to what was reported in [5] for a DF-CO_2 laser generating on a mixture of 9% D_2 - 9% F_2 - 36% CO_2 - 0.5% O_2 - 45.5% He.

For purposes of comparison, Figure 3 includes $\varepsilon(\alpha)$ relationships for an HF laser (see also [3]) obtained for two different mixtures at $p_0=1$ atm and $T_0=300$ K. It can be seen that, in the case of the HF laser, the $\varepsilon(\alpha)$ thresholds lie at relatively low α, and the relationships show no tendency to saturation in the α range in question; but the maximum energy doesn't exceed 0.015 J/cm^3 and maximum chemical efficiency is just 1.5%.

Figure 4 shows the relationship of energy density of a DF-CO_2 laser to the content of CO_2 in the mixture. The relationship was plotted for the case of invariant chemical reaction conditions [3, 10], i.e., the initial reaction rate and the rate of circuit breaking were maintained constant. This was achieved by specific modification of the initial concentration of oxygen and the initiation energy (see Figure 4). It can be seen that the energy density rises steadily with increasing CO_2 concentration up to about 20% but doesn't vary further even up to total replacement of He by CO_2. From a comparison of these data with known results (cf [4, 15], for example) it follows that the observed (in [4, 15]) drop of specific energy with increase in CO_2 concentration above 10% (constant electric energy of initiation) was due to a reduction of the reaction rate caused by a rise in the rate of circuit breaking at the CO_2 molecules and an increase in the specific heat of the mixture.

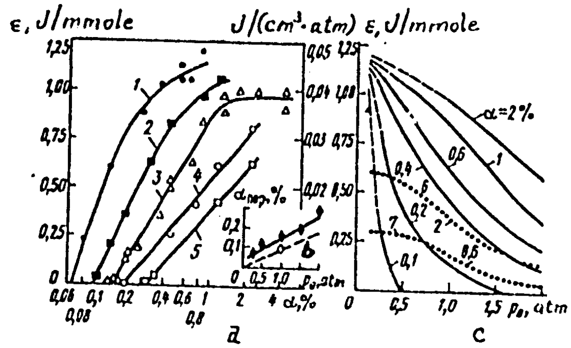
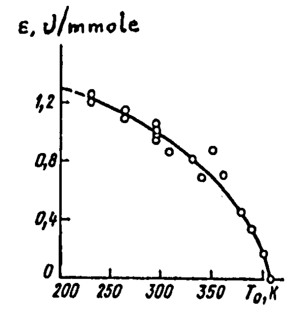


Figure 5. Relationships $\varepsilon(\alpha, p_0)$ (graphs a and c), and $\alpha_{nop}(p_0)$ (graph b [subscript "nop" = threshold]) for a DF-CO_2 laser at p_0 = 0.25 atm (1), 0.5 atm (2), 1.0 atm (3), 1.5 atm (4), 2.0 atm (5); and $\varepsilon(\alpha, p_0)$ for an HF laser (dotted curves 6, 7).

The relationships of energy density to overall pressure of the mixture have already been investigated. However, the investigations were carried out only for some single fixed value of the initiation energy [4, 15, 18]. It was therefore of interest to obtain a set of $\varepsilon(\alpha, p_0)$ relationships for a wide range of variation of α and p_0. It can be seen from Figure 5a that the curves have a threshold which, as Figure 5b shows, is proportional to the pressure; the energy density for all p_0 increases steadily with α, displaying a tendency toward saturation at large α. Figure 5b illustrates the experimental fact noted above, that laser action in a $DF\text{-}CO_2$ laser takes place only at the explosive state of the chemical reaction. The solid line in Figure 5b shows the $\alpha_{nop}(p_0)$ relationship for lasing derived from Figure 5a, and the broken line shows the relationship of the mixture explosion thresholds to pressure as obtained from data in [10], taking into account additional circuit breaking in the process $D + DO_2$ [16] (the explosion threshold which we found experimentally is identified by the marker). It can be seen that, as p_0 rises, the thresholds for initiation of explosion and lasing come closer together. The relative position of explosion and lasing thresholds in an HF laser ($p_0 \approx 1$ atm) were discussed in [3]; in particular, with the initiating-pulse durations which were used there, the thresholds of explosion and laser action just about coincided. With shorter initiation laser action is possible in the pre-explosion region also [17].

The $\varepsilon(p_0)$ relationships for fixed values of α were derived from Figure 5a and included in Figure 5c. It can be seen that as p_0 rises the molar energy yield drops (especially sharply in the case of weak initiation). This is due mainly to the ascending role of circuit breaking processes in triple collisions (and, accordingly, to the relative reduction of the overall chemical reaction rate) as compared with the bimolecular processes of circuit perpetuation, energy transfer and relaxation. At low pressures ($p_0 \lesssim 0.1$ atm) in the $\alpha \approx 0.1$ - 2% range, all the curves tend toward $\varepsilon_{max} \approx$ ≈ 1.2 J/mmole with a corresponding chemical efficiency of 4.5%, whereas at $p_0 \approx 1$ atm the maximum efficiency amounts to 3.5%.

Figure 6. Relationship of energy density of a $DF\text{-}CO_2$ laser to the initial temperature of the mixture.



By simple estimates, the limit value of laser energy for the given mixture in the absence of any relaxation processes is ~ 4.5 J/mmole. Therefore, the energy shortage occurring at $p \lesssim 0.1$ atm is caused mainly by relaxation processes.

Going back to Figure 5c, two $\varepsilon(p_o)$ relationships are shown for an HF laser using a mixture of 3.7% H_2 - 11.1% F_2 - 2.2% O_2 - 83% He (see also [3]). It can be noted that these relationships bear the same character as in the case of the DF-CO_2 laser. However, at different values of α they tend toward different values of ε_{max} in the low pressure region. As can be judged from the Figure, $\varepsilon_{max} \sim \sqrt{\alpha}$. This also follows from a simple model of the HF laser in which the principal cause of disrupted laser action is the square law--as regards HF molecule concentration--process of HF relaxation to HF (see [3], for example). The chemical efficiency corresponding to maximum energy density at $\alpha = 2\%$ is $\sim 3\%$.

To the best of our knowledge, the literature does not provide complete relationships between laser action energy and initial temperatures for the lasers in question. Figure 6 shows that relationship for a DF-CO_2 laser using a mixture of 5% D_2 - 15% F_2 - 25% CO_2 - 1% O_2 - 54% He at $p_o = 1$ atm and $\alpha \approx 1\%$. It is significant that cooling of the mixture from 300 down to about 200 K leads a 20-30% increase in the molar energy yield, but heating results in a sharp yield reduction. At $T_o \approx 410$ K the mixture exploded spontaneously, but cooling below 200 K resulted in intensive condensation of CO_2 molecules.

These relationships were not investigated for HF lasers. However, it is known [19] that cooling of a stoichiometrically composed mixture, not diluted with helium, to 213 K at $p_o = 0.15$ atm did not result in a noteworthy increase in the energy yield.

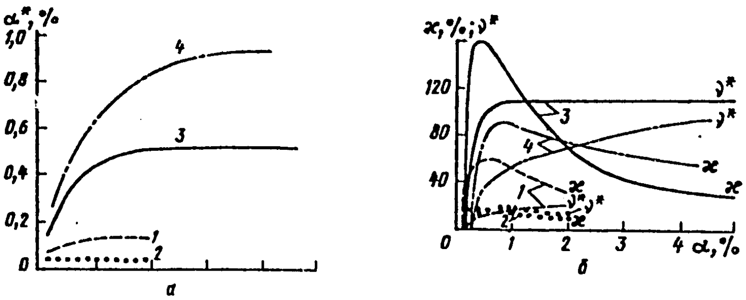


Figure 7. The relationship of α^* (a) and $\varkappa$, ν^* (b) to initiation for HF and DF-CO_2 lasers using mixtures of 3.7% H_2 - 11.1% F_2 - 2.2% O_2 - 83% He (1), 14.5% H_2 - 43.5% F_2 - 8.5% O_2 - 33.5% He (2), 5% D_2 - 15% F_2 - 25% CO_2 - 1% O_2 - 54% He (3), and 5% D_2 - 15% F_2 - 79.4% CO_2 - 0.6% O_2 (4).

In conclusion, we will compare the quantum yields of both lasers and their energy efficiencies at various initiation energies. The quantum yield was defined as the ratio of the number of laser action photons to the number of photons of the light absorbed by fluorine molecules to termination of lasing. Energy efficiency was defined as the ratio of total laser action energy to the energy of the light absorbed by fluorine molecules during the entire flash. The comparison was made for lasers operating at $p_0 = 1$ atm, $T_0 \approx \approx 300$ K and $\alpha = 0 - 5\%$. Figure 7a shows the levels of fluorine molecule dissociation to end of lasing (α*) needed for calculation, relative to the total initiation energy. It can be seen that the initiation energy used in lasing α* (determined to about 50% accuracy) tends toward saturation as α rises in the case of both HF and DF-CO_2 lasers, whereby α* is substantially less for the HF laser than for the DF-CO_2 laser. It is therefore to be expected that shortening of the duration of the initiating pulse will lead to a relatively faster increase in the efficiency of utilization of the initiating light in the case of the HF laser [3].

The experimentally derived values for the quantum yield ν* and energy efficiency $\varkappa$ relative to the total initiation energy are shown in Figure 7b. Comparing the obtained characteristics, one is able to note the following. In the case of both lasers, ν* as well as $\varkappa$, with α rising, increase rapid-right up to $\alpha \sim 0.5\%$, where $\varkappa$ has a clearly expressed maximum and ν* practically reaches its limit. It is seen, moreover, that for the DF-CO_2 laser the limit characteristics shown are several times higher than for the HF laser. This is, however, valid only for the mixture compositions and length of initiation investigated by us. For example, in [11] they found $\alpha_{max} = 0.035\%$ and $\epsilon_{max} \approx 0.019$ J/cm^3 for an HF laser using a mixture of 18% H_2 - 64% F_2 - 9.7% O_2 - 8.3% Ar at $p_0 \approx 0.75$ atm, $\alpha \sim 0.7\%$ with an analogous shape of the initiating pulse, which is not much different from our findings; but they found $\nu^*_{max} = 70$, which is some four times higher than our finding. A gain in ν^*_{max} by about 1.5 - 2 times is due to the fact that the chemical length of the circuit in [11] is some 1.5 - 2 times greater than for our mixtures (we note that mixture preparation in a long circuit entails definite technical difficulties). A further gain by about a factor of 2 apparently has to do with the fact that, firstly, the absolute concentration of atoms entering into the chemical reaction was higher (and the reaction rate along with it) and, secondly, the pressure was closer to optimum (see [3], for example).

As was demonstrated in [20, 21], increasing the rate of rotation relaxation in an HF laser by introducing suitable relaxants leads to a 2-3-fold enhancement of its energy characteristics. Hence, the HF laser characteristics which we have reported can be upgraded, i.e., under conditions of the initiation we used, their values will approximate the corresponding values for a DF-CO_2 laser.

It is important to note that there is is at present no satisfactory model for a DF-CO_2 laser which would explain, on the one hand, the existence of energy density saturation with rising initiation energy in helium-diluted mixtures and, on the other hand, the absence of saturation in mixtures, not diluted with helium, having a high CO_2 content. It is thus difficult to come up with hard and fast recommendations on optimum mixture composition for the DF-CO_2 laser. It follows from the results obtained that, with relatively weak initiation ($\alpha \lesssim 1\%$), the most expedient is a mixture of 5% D_2 - 15% F_2 - 25% CO_2 - 1% O_2 - 54% He which, while providing high energy characteristics, is sufficiently stable and therefore easy to prepare. In the case of strong initiation, however, a mixture with a higher content of CO_2 and F_2 should be used.

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5454
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PHYSICS

UDC 535.36

METHOD FOR MEASURING THE GEOMETRIC PARAMETERS OF QUASIGAUSSIAN LASER BEAMS

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 5 No 11, 1978, received 1 March 1978 pp 2457-2459

[Article by D. V. Vlasov, V. V. Korobkin, R. V. Serov, Physics Institute imeni P. N. Lebedev of the USSR Academy of Sciences, Moscow]

[Text] Laser beams with quasigaussian intensity distribution are frequently used to perform experiments in various areas of quantum electronics. For precise processing of the measurement results it is necessary to know the geometric parameters of such beams with good accuracy: the diffraction divergence radius $z_0 = kw_0^2/2 = \pi w_0^2/\lambda$ (w_0 is the peak radius of the beams; $k = 2\pi/\lambda$ is the wave number) and the constriction position of the beam z_π. In practice all of the existing methods of measuring the configuration of a beam are based on direct or indirect photometric measurements of the intensity distribution of it [1-4]. The characteristic error for such measurements is rarely less than 10 percent.

In this paper two methods are proposed for measuring the parameters of quasigaussian beams. They are quite simple from the point of view of calculations and do not require either direct (that is, the construction of a blackening curve) or indirect (for example, the use of filters with known optical densities) photometry, and they also provide useful information about the structure and aberrations of the phase front of the beam.

1. Uniform Phase Distribution

The investigated beam is incident inclined to a plane-parallel transparent plate, the thickness of which is significantly less than the radius of the diffraction divergence of the beam ($t \ll z_0$). On reflection, two beams arise of approximately equal intensity, the axes of which are parallel and are shifted by the distance $x_0 = t \sin 2i/\sqrt{n^2 - \sin^2 i}$, where i is the angle of incidence, n is the index of refraction of the plate material.

The interference pattern occurring in the z-plane for $x_0 > w_0$ is a system of bands (Figure 1), the spacing between which is

$$\Delta x \approx \lambda |R(z)| / x_0, \quad (1)$$

where $R(z)$ is the radius of curvature of the wave front of the beam in the z cross section. For $z - z_\pi >> z_0$, the radius of curvature of the phase front is in practice equal to the distance to the beam constriction, and by two or several measurements (which must be performed on both sides of the constriction) it is possible to find the constriction position of the beam with high accuracy. Then, measuring $R(z)$ near the constriction, we find the radius of the diffraction divergence of the beam $z_0 = \sqrt{(z_1 - z_\pi)(R(z_1) - z_1 + z_\pi)}$ and the peak radius of the beam respectively at the constriction $w_0 = \sqrt{z_0 \lambda / \pi}$ and the angle of diffraction divergence $\theta = w_0/z_0 = \lambda/(\pi w_0)$. Let us note that for beams with a parabolic phase front (in particular, for gaussian beams) the bands must be strictly rectilinear.

Generally speaking, it is necessary to consider that the formula (1) is of an approximate nature inasmuch as the bands are not purely sinusoidal. In the interference pattern the sinusoidal bands are superposed on the superposition of two gaussian distributions. The synthetic error occurring in this case $\delta w_0/w_0$ is equal with respect to order of magnitude to $\sim \gamma x_0/(4w_0)$, where γ is the relative error in measuring the band width. Therefore, when using formula (1) to calculate the beam parameters, the total error can reach several percentages. The above indicated systematic error can be excluded by comparing the position of the peaks and the minima of the interference pattern and the corresponding values calculated by computer using the formula

$$J(x, z) = Ae^{-2x^2/w^2}\left[\operatorname{ch} \frac{2xx_0}{w^2} + \cos\left(\frac{kxx_0}{R} + \Phi_0\right)\right].$$

Here it is expedient to consider the restrictions connected with nonparallelness of the faces of the plate and the optical relay of one of the interfering beams in the plate material. Let the nonparallelness of the plate faces be α, then the reduced difference in optical paths of the interfering beams $L = 2l \cos i / \sqrt{n^2 - \sin^2 i}$, the restriction on the angle between the reflecting faces of the plate assumes the form $2n\alpha << \lambda/w_0$, and the restriction on the plate thickness is $L << z_0$.

It is easy to see that the first condition does not create theoretical limitations for measuring real beams. In practice, in order to check the suitability of the plate, it is necessary to make several exposures of the interference pattern, rotating the plate around the normal to the reflecting surface. If we cannot record the variation in the interference pattern, then the plate is totally suitable for measuring the parameters of the test beam. The second condition, generally speaking, imposes quite rigid restrictions on the parameters of the measured beam. Thus, in accordance with the second condition for beams with $z_0 \sim 20$ mm it is difficult to find an appropriate plate inasmuch as it is technologically complicated to manufacture a high-quality, plane-parallel plate less than a millimeter thick.

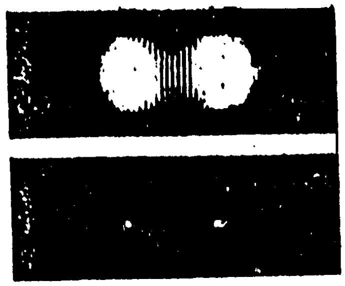

Figure 1. Distribution of the intensity of beams reflected from a plane-parallel plate.

At the top is the characteristic interference pattern; the intensity distribution in the constriction region appears below.

Figure 2. Interference pattern at the exit of a Michelson interferometer.

It is possible to attenuate the above-presented restrictions significantly by using another, more complex system for splitting the test beam. For example, in order to measure the parameters of strictly focused beams (with small z_0) it is expedient to use the double beam-refracting plane-parallel plate of Iceland spar with a polarizer installed behind it. In this case the interference pattern is created by ordinary and extraordinary beams, the intensities of which can always be made equal by appropriate setting of the polarizer. The beam parameters with z_0 on the order of several millimeters can be measured in this system.

2. Two Dimensional Phase Distribution

The studies of the perturbations and aberrations of the phase front of beams using the Michelson interferometer have been performed many times [5, 6]. In contrast to the above-enumerated paper, in the method that we propose a zero-order interference pattern is used, that is, for beams with a plane front, interference rings (or bands) are absent. The investigated beam is passed through the Michelson interferometer. It is possible to obtain two beams at the exit, the axes of which exactly coincide, but the constrictions are shifted by $\Delta = z_{\pi_1} - z_{\pi_2}$ equal to the difference of the optical paths of two arms of the interferometer. By observing the system of interference rings (Figure 2) in the plane $z = \Delta/2$, that is, between constrictions, we obtain 100 percent modulation of the intensity distribution with respect to the entire field of view. The radii of the rings $\rho_m(z)$ are uniquely related to $R(z)$ by the expression

$$\rho_{m+1} - \rho_m = |R|\lambda/2.$$

In this method the systematic error is absent, and the accuracy of the measurement is determined by the random adjustment errors and measurement of the ring radii. The remaining beam parameters are calculated by the measured value of the beam radius and Δ (just as in the first method).

The above-described methods were used by the authors for a number of years to measure the geometric parameters of a neodynium glass laser emission with modulated Q-factor and also the emission of the helium-neon laser. The method of one-dimensional phase distribution is easily used here to detect and measure the spherical aberration of the phase front of the beam on the order of $\lambda/10$ [7] and, correspondingly, with respect to the two-dimensional phase distribution--astigmatism (in particular, for the beam in figure 2 $R_{min}/R_{max} = 0.89$).

As an example of such measurements let us present a description of one of the experiments in measuring the geometric parameters of the beam from a pulsed unimodal neodynium laser with Q-factor modulation. The beam was focused by an objective with a focal length of 50 cm. For the measurements by the method of one-dimensional phase distribution, a plate 1.02 mm thick was used which was installed directly after the objective at an angle close to 45°. The distribution of the intensity of the interference pattern of the reflected beams was recorded on a photographic plate. After each pulse, the plate was shifted along the Z-axis a distance of 3 cm near the constriction and 10 cm farther. Thus, 20 points were obtained. A straight line, the intersection of which with the z-axis corresponded to the beam constriction was drawn through the four edge points $R(z)$ by the least squares method. By the six points located directly next to the constriction, the value of $z_0 = 25.5 \pm 3$ mm was obtained and $w_0 = 92.7 \pm 6$ microns and $\theta = 3.6 \pm 2.5$ mrads, respectively.

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10845
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PHYSICS

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SOME RESULTS OF OPTIMIZING THE COMPOSITION OF ACTIVE MEDIA AND THE OPERATING PARAMETERS OF A GAS-DISCHARGE CO-LASER

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 5 No 11, 1978 Received 1 March 1978 pp 2459-2461

[Article by G. M. Grigor'yan, B. M. Dymshits, G. V. Ivanov, Ya. P. Koretskiy, I. V. Kochetov, V. M. Lamonov, V. G. Pevgov, V. F. Sharkov]

[Text] The optimization of the compositions of the working mix and the operating conditions of a fast-flow CO-laser with longitudinal discharge (ℓ = 2m) was carried out on the experimental setup described in reference [1]. The purpose of optimization was to obtain maximum efficiencies and specific power output. The composition and flow rate of the gas, the pressure in the discharge tube, and the energy contribution per unit volume of discharge were varied during the experiments.

Numerical calculations were first performed [2, 3], on the basis of which the range of variation of the operating parameters, which was of interest, was determined. The reliability of the calculations was confirmed [4] by comparison with the experiments studying the spectral composition of the radiation and the amplification coefficient of the weak signal.

Some of the results obtained at the present time are presented in the table. The continuous operating time of the laser under the conditions presented in the table was units to tens of minutes depending on the gas flow rate, and it was limited by the pressure buildup in the vacuum tank into which it was exhausted.

One of the basic causes leading to improvement of the output parameters by comparison with the ones published in [1], in our opinion, is more careful drying of the working gases. The drying was done by passing the components of the gas mixture through vessels filled with alumogel and installed in a high-pressure region ($\sim$100 kg/cm^2) in front of the reducers. The experiments were performed for a dew point of the working mix of no more than -50°C. The moisture was controlled by the condensation and coulometric methods.

Характеристики и параметры лазера (1)	(2) Опыты				
	1	2	3	4	5
КПД, % (3)	44,2	42,0	31,8	28,9	27,7
Удельный энергосъем, Дж/г (4)	1325	1069	332	288	251
Выходная мощность лазера, Вт (5)	263	252	560	830	849
Удельный энерговклад, Дж/см³ (6)	0,72	0,72	2,12	3,46	3,68
Давление в разрядной трубке, мм рт. ст. (7)	5,5	7,0	12,0	18,0	23,5
Полный ток разряда, мА (8)	70	75	160	180	180
Расход компонентов смеси, нл/с: (9)					
CO	0,059	0,0544	0,449	0,784	0,818
He	0,524	0,784	4,98	8,12	10,79
	0,023	0,021	0,174	0,306	0,317
O_2	0,00176	0,0016	1,013	0,024	0,0244
Параметр $(E/N) \times 10^{17}$, усредненный по длине трубки, В × см² (10)	20,2	15,0	11,9	11,0	9,14

Note: The presented values contain three-four significant figures and were obtained when using the computer for automatic gathering and processing of the test stand data. The sensor error when measuring the output power of the radiation was 6 percent, current and voltage 1.5 percent, component flow rates 2-5 percent (depending on the magnitude of the flow rate).

Key:
(1) laser characteristics and parameters
(2) experiments
(3) efficiency, %
(4) specific energy contribution, joules/gram
(5) laser output power, watts
(6) specific power input, joules/cm^3
(7) pressure in the discharge tube, mm Hg
(8) total discharge current, milliamps
(9) flow rate of the mixture components, n liters/sec:
(10) Parameter $(E/N) \times 10^{17}$ averaged along the length of the tube, B x cm^2

In addition to moisture, the impurities in the initial gas also have important influence. Thus, for example, when using carbon monoxide containing 2.7 percent H_2 and 0.6 percent CH_4, the radiation power turned out to be more than two times below that when using carbon monoxide containing 0.1 percent H_2 and 0.1 percent CH_4. The qualitative explanation of this fact can be obtained from comparing the relaxation constants. Thus, the VT-relaxation constants for $CO-H_2$ and $CO-H_2O$ at a temperature of 300°K exceed the analogous constants for CO-He by 1.5 and 3.5 orders respectively. At lower temperature, the excess is still more [3].

In addition, the increase in output power, specific power output and deficiency unconditionally was promoted by an increase in the length of the discharge zone which made it possible to increase the specific energy contribution. As a result, the resonator which was used with 50 percent transmission of the output mirror began to operate more efficiently.

The results presented in the table were obtained when using an external resonator; the ends of the discharge tube were covered with CaF_2 windows fastened at the Brewster angle. In order to estimate the effect of the losses connected with the presence of windows, a special series of tests were run on the efficiency of the laser.

An adjustable unit with an internal "blind" mirror was installed in place of one optical window in the discharge tube. The other end of the tube, was as before covered with a CaF_2 window. Between this window and the plane semitransparent germanium mirror with 50 percent transmission another CaF_2 plate was installed at the Brewster angle. The output power of the laser was measured in the presence of this additional plate (P_1) and in the absence of it (P_2). As a result of processing the experimental data from 15 experiments, the ratio $P_1/P_2 = 0.862 \pm 0.015$ was obtained (the fiducial interval was determined for probability of 0.95). It must be noted that the role of the intraresonator losses connected with the presence of optical windows of CaF_2 at the ends of the discharge tube still depends on the operating conditions of the laser. Nevertheless, on the basis of the experiments that were performed it is possible to propose that the replacement of the external resonator by an internal one leads to a noticeable increase in output power and efficiency of the laser by comparison with the table data.

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PHYSICS

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EVALUATION OF THE ACCURACY OF THE LASER DOPPLER VELOCITY METER

Leningrad OPTIKA I SPEKTROSKOPIYA in Russian, Vol 44, No 6, Jun 78, pp 1153-1156

[Article by I. P. Lukin]

[Text] A study is performed of the perturbing effect of atmospheric turbulence on the operation of a laser Doppler velocity meter. An analytic expression is obtained, relating the error in measurement of velocity to the parameters characterizing the geometry of the meter and the conditions of turbulence. The question of methods of decreasing the measurement error is discussed.

In recent years, laser Doppler velocity meters (LDVM's) have become widespread [1]. These devices use the Doppler frequency shift of a signal reflected from a moving object to determine the velocity of the object. These systems are particularly useful for studies of atmospheric turbulence by means of the scattering of light on aerosol particles (natural or artificially introduced) in the atmosphere. The primary advantage of LDVM's include: capacity for remote measurement, noncontact measurement, linearity with respect to velocity, as well as their broad range of measurement and practically unlimited maximum measurable velocities. The problem of estimating the accuracy of such instruments has formed the subject of a number of works [1-3], in which various reasons for spreading of the Doppler signal have been analyzed: the influence of physical processes occurring in the air stream; the influence of certain factors in the optical portion of the system. However, since the mutual coherence of the sources is significant in such systems, and since it is the coherent properties of the radiation which are most highly distorted during propagation through a turbulent atmosphere, the question arises of the error of velocity measurement introduced by turbulence. The study of this question, particularly the relationship of this error to the error introduced by fluctuations in the velocity of scattering objects, is the subject of the present report.

1. For definition, let us analyze the following measurement system: two mutually coherent point sources are located at points $(0, -\rho_0)$ and $(0, \rho_0)$, respectively, and a receiver is located at point $(0, \rho_\pi)$. The receiver is a square-law detector, reacting to the power of the incident radiation:

$$i(t) = mI(\rho_\pi;\ t), \tag{1}$$

where m is the effectiveness factor of the receiver, $I(\rho_\pi;\ t)$ is the instantaneous value of intensity of the reflected radiation at the point where the detector is located.

Suppose the object from which the laser radiation is reflected consists of a cloud of chaotically distributed scattered bodies, the dimensions of which are such that the fields created by the sources are locally plane, coherent waves within the limits of the clouds of bodies. We will also assume that the distance between the scattering objects is rather great and that the attenuation of the field due to scattering is slight; therefore, the field, reflected once, can be summed as to intensity [4]:

$$I(\rho_\pi;\ t) = \sum_{l=1}^{N} I_l(\rho_\pi;\ t), \tag{2}$$

where

$$I_l(\rho_\pi;\ t) = \frac{U_0^2 S_l^2}{L^4} e^{2\chi(L,\, v_{0l}t;\, 0,\, \rho_\pi;\, t)} \Big\{ e^{2\chi(0,\, -\rho_0;\, L,\, v_{0l}t;\, t)} + e^{2\chi(0,\, \rho_0;\, L,\, v_{0l}t;\, t)} +$$

$$+ 2\cos\left[\frac{2k\rho_0 v_{0l}t}{L} - i\varphi(v_{0l}t;\ t)\right]\Big\},$$

$$\varphi(\rho;\ t) = \psi(0,\ -\rho_0;\ L,\ \rho;\ t) + \psi^*(0,\ \rho_0;\ L,\ \rho;\ t),$$

$$\psi(r;\ r';\ t) = \chi(r;\ r';\ t) + is(r;\ r';\ t),$$

$\chi(r;\ r';\ t)$, $s(r;\ r';\ t)$ are fluctuations in the logarithm of amplitude and phase, arising upon propagation from point r to point r' at moment in time t; N is the number of scattering objects; U_0 is the initial amplitude of the field at the source; S_ℓ is the amplitude function of scattering of the ℓth member of the set; $k = 2\pi\lambda^{-1}$, λ is the wave length of the radiation in free space; L is the distance from the sources to the scattering volume; $v_{0\ell}$ is the velocity of the ℓth scattering object.

Let us analyze the case in which the velocities of the scattering objects are steady, random processes, the statistical properties of which are identical for all scattering objects ($\overline{v}_{0\ell} = \overline{v}_0$ is the mean velocity, $\sigma_{v\ell}^2 = \sigma_v^2$ is the dispersion of velocity fluctuations.

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In order to measure the speed of movement of an object, the recorded current is subjected to correlation analysis, and the position of the maximum of the spectrum is determined. If there are no fluctuations, the spectrum of current consists of a set of delta functions, i.e., the system allows precise estimation of the speed of movement of an object. However, fluctuations in the radiation, caused by passage through a turbulent atmosphere and fluctuations in the speeds of scattering objects, lead to errors in velocity measurement. The relative error of measurement is related to the expansion of the spectrum

$$\frac{\Delta v_0}{v_0} \simeq L\Delta f\,(k2\rho_0 v_0)^{-1},$$

where Δf is the half-width of the current spectrum. We know [5] that $\Delta f \simeq \tau_{kop.}^{-1}$, where $\tau_{kop.}$ is the correlation time of the photocurrent. The normalized self-correlation function of photocurrent is

$$\gamma_i(\tau) = \Gamma_i(\tau)\,\Gamma_i^{-1}(0), \tag{3}$$

where

$$\widetilde{\Gamma_i(\tau) = \lim_{T\to\infty} \frac{1}{T}\int_0^T [i(t) - \overline{i(t)}][i(t+\tau) - \overline{i(t+\tau)}]\,dt},$$

$$\overline{i(t)} = \lim_{T\to\infty} \frac{1}{T}\int_0^T i(t)\,dt = mU_0^2 L^{-4}\sum_{l=0}^{N} S_l^2\left[e^{4B_\chi(|\rho_0+\rho_n|)} + e^{4B_\chi(|\rho_0-\rho_n|)}\right];$$

$B_\chi(\rho)$ is the correlation function of the fluctuations in the logarithm of amplitude [6], while the wavy overline represents averaging with respect to fluctuations in the velocities of scattering objects.

Since the fluctuations in the complex phase $\psi(r;\, r';\, t)$ in the area of applicability of the method of smooth perturbations are distributed normally [7], while all the scattering objects are statistically equally probable, if $\tau \ll \tau_0 = 2\rho_0\bar{v}_0^{-1}$

$$\widetilde{\gamma_i(\tau) \simeq \exp\left\{-\left[\frac{\tau}{\tau_1(v_0,\, \bar{v})}\right]^{5/3}\right\}\cos\left(\frac{2k\rho_0 v_0}{L}\tau\right)}, \tag{4}$$

where

$$\tau_1(v_0, \bar{v}) = \left(\frac{8}{3}\int_0^1 dx\,|xv_0 - v|^{5/3}\right)^{-3/5}\sqrt{\frac{L}{k}}\,D^{-3/5}\left(\sqrt{\frac{L}{k}}\right);$$

$D(\rho) = 0.27\ C_\Sigma^2 k^2 L^{5/3}$ is the structural function of the complex phase of a spherical wave; C_Σ^2 is the structural parameter of turbulence. $\bar{v}$ is the value of wind speed on the track.

If we also presume that the fluctuations in velocities of scattering objects are distributed normally, we can then derive the final expression for the normalized correlation function

$$\gamma_i(\tau) \simeq \exp\left\{-\left[\frac{\tau}{\tau_1(\bar{v}_0, \bar{v})}\right]^{5/3} - \frac{2k^2\rho_0^2\sigma_v^2}{L^2}\tau^2\right\}\cos\left(\frac{2k\rho_0\bar{v}_0}{L}\tau\right), \qquad (5)$$

2. It is not difficult to see that the error in measurement of velocity will be

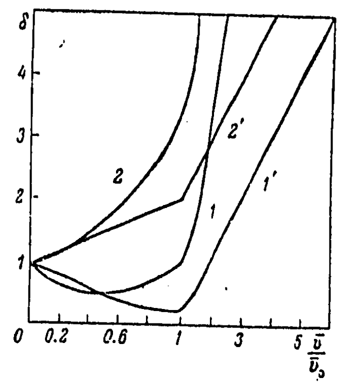
$$\beta(\bar{v}_0, \bar{v}) = \frac{\Delta v_0}{v_0} \sim \begin{cases} \left[\frac{8}{3}\int_0^1 dx\,|x\bar{v}_0 - \bar{v}|^{5/3}\right]^{3/5} \frac{\sqrt{Lk^{-1}}\,D^{3/5}(\sqrt{Lk^{-1}})}{v_0(2\rho_0)} & D\left(\sqrt{\frac{L}{k}}\right) \geqslant d, \\ 2^{-1/2}\sigma_v v_0^{-1} & D\left(\sqrt{\frac{L}{k}}\right) < d. \end{cases}$$

where $d = [\sqrt{2}\,\rho_0\sqrt{kL^{-1}}\,\sigma_v v_0^{-1}]^{5/3}$.

As would be expected, the error results from fluctuations in the velocity of the object, and from the turbulence of the atmosphere. If the fluctuations in velocity of the object and caused by fluctuations in wind speed, the error will not be great, since in the atmospheric layer near the ground $\sigma_v \bar{v}_0^{-1} \simeq 0.1$ [6]. If $\rho_0 \leq \sqrt{Lk^{-1}}$, the error introduced by turbulence will be significant (in comparison to the error resulting from fluctuations in the velocities of the scattering objects), even with slight turbulence. If the turbulence is strong or if the radiation path is long, the main contribution to the error in measurement of velocity will always be that of turbulent distortions.

When the primary contribution to the measurement error is that of turbulence, the error increases with increasing intensity of the turbulence $(C_\varepsilon^2)^{3/5}$. We can see that the relative error of velocity measurement if proportional to $L^{3/5}$ and $k^{1/5}$. A decrease in the error resulting from turbulence is possible by increasing the distance between the sources and wave

Figure. 1,2 - Spherical wave; 1', 2' - plane waves; 1, 1' - $\overline{v}_0 \uparrow\uparrow \overline{v}$; 2, 2' - $\overline{v}_0 \uparrow\downarrow \overline{v}$.



lengths. The normalized error $\delta = \beta(\overline{v}_0, \overline{v})\beta^{-1}(\infty, \overline{v})$ depends essentially on the ratio of mean wind speeds and speeds of scattering objects, as well as their mutual orientation (see figure). The difference between curves 1 and 2 is explained by the fact that the speed of transfer of turbulent heterogeneities acting on the radiation is $\simeq \overline{v}_0 - \overline{v}$, and in minimal where $\overline{v}_0 \uparrow\uparrow \overline{v}$ and maximal where $\overline{v}_0 \uparrow\downarrow \overline{v}$. The limiting value of error $\beta(\infty, \overline{v})$ is

$$\sqrt{\frac{L}{k}}\, D^{3/5}\left(\sqrt{\frac{L}{k}}\right)(2\rho_0)^{-1}.$$

3. A similar analysis can be performed for the other initial distribution of radiation at sources, for example, for plane waves propagating at and to each other. The variation in the normal error of velocity measurement as a function of the ratio of mean velocities of the wind and the reflecting objects is shown in the figure. We note that the maximum value of error as $|\overline{v}_0| \to \infty$ is

$$\beta(\infty, \overline{v}) \sim \left[\sqrt{kL}\,\sin(\varphi)\right]^{-1}\left[D^{p}\left(\sqrt{Lk^{-1}}\right)\right]^{3/5},$$

where $D^P(\rho) = \frac{8}{3} D(\rho)$ is a structural function of the fluctuations in the complex phase of the plane wave.

4. We note in conclusion that the error introduced by turbulence is insignificant in laboratory measurements and over short path lengths ($L \leq$ 10 m), but become significant during propagation in the lowest layer of the atmosphere over long distances ($L \simeq$ 100 m-1 km). Therefore, in these cases, it is necessary to consider the influence of atmospheric turbulence along with other distorting factors.

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SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

SCIENTIFIC RESEARCH SEMINARS ON AEROMECHANICS AND GAS DYNAMICS (DIRECTOR ACADEMICIAN G. I. PETROV)

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA SER. MATEMATIKA MEKHANIKA in Russian No 6 1978 pp 83-84

[Text]

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14 September	M. M. Golomozov, "Study of Spatial Currents from Departing Shockwaves."
21 September	S. Ya. Gertsenshteyn, Ye. B. Rodichev, V. M. Shmidt, "Interaction of Three Dimensional Waves and the Occurrence of Turbulence in the Presence of a Convective Instability."
28 September	V. V. Tyurev, "Thin Surface in an Ideal Liquid Flow."
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3 May	V. I. Myshenkov, "Numerical Investigation of a Separated Flow in Front of a Recess."
10 May	V. P. Myasnikov, "Theory of Mixing in a Boiling Layer."
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PUBLICATIONS

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MANIPULATING ROBOTS, DYNAMICS AND ALGORITHMS

Moscow MANIPULYATSIONNYYE ROBOTY. DINAMIKA I ALGORITMY in Russian 1978 signed to press 6 Apr 78 pp 4-7

[Annotation and Table of Contents of book by Ye. P. Popov, A.F. Vereshchagin and S.L. Zenkevich, Izdatel'stvo "Nauka", 4,900 copies, 400 pages]

[Annotation]

[Text] The book sets forth methods of studying the complete spatial dynamics of the manipulating systems of robots as complex, multi-link mechanical objects with an arbitrary kinematic configuration and with any number of degrees of mobility. These methods make it possible to automate, in a convenient form, the process of simulating on digital computers and analog-to-digital converters the spatial dynamics of the manipulator with an actuating control system from the initial data without writing out equations.

Algorithms for automated planning of the robot's controlled movement, as well as several algorithms for data processing in robot control systems and the principles of constructing control systems are formulated. A general classification of robots is proposed, according to the control principles, which encompasses the perspectives for their further development and use in the national economy, in studying and exploring the ocean, underground regions, etc.

The book's main content pertains to the results of the authors' own studies, with partial inclusion of other studies. The presentation of the material is easily understandable for a broad range of engineers, scientific associates, graduate students and students in senior courses.

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SIMULATION OF DISCRETE SYSTEMS ON COMPUTER DISCUSSED

Moscow MODELIROVANIYE SLOZHNYKH DISKRETNYKH SISTEM NA EVM TRET'YEGO POKOLENIYA (OPYT PRIMENENIYA GPSS) [Simulation of Complex Discrete Systems on a Third Generation Electronic Computer] in Russian 1978 signed to press 23 Jan 78 pp 2, 5-6, 161

[Annotation, excerpts from foreword and table of contents from book by O. V. Golovanov, S. G. Duvanov and V. N. Smirnov, Energiya, 15,000 copies, 161 pages]

[Text] The book presents a brief description of the system of statistical simulation of the General Purpose Simulation System/360. There is a discussion of the use of the language of simulation in a number of specific problems involved in data processes, industrial processes, breakdown of instruments, etc. The book may be of assistance in setting up the system discussed of simulation on a unified system of an electronic computer.

The book may serve as a manual for this language of simulation and be useful to engineers and researchers studying problems of simulation on computers.

Foreword

[Excerpts] This book is devoted to a discussion of the potentials of using GPSS [general purpose simulation system] for simulating the most varied systems (henceforth the abbreviated Russian name for the GPSS language will be given: OTsSM--general purpose simulation system).

This language has been included in the software of machines of the IBM firm since 1962 and is now one of the most popular languages for simulation modeling (along with such languages as SIMSKRIPT, SIMULA and CSL). It is particularly well adapted for studying queueing problems. Standard components of actual systems, such as units, storages and switches were inserted as elements of this language. An adequate set of such components and the programmed execution of the algorithms for their functioning make it possible to construct complex models, while retaining the writing customary for the planners.

The material in the book is set forth in the following order.

Chapter 1 gives a brief description of the simulation system.

Chapter 2 illustrates the possibilities of using the simulation system in solving queueing problems.

The results of the simulation are compared with the results obtained by the analytic method.

Chapter 3 discusses the use of the simulation language in a number of more complex problems involving instrument breakdowns, transmission and processing of information and also industrial processes.

For one of the problems, in addition to the program in the simulating language, a variant of the program is given using ALGOL. The reader may compare the various potentials for simulation and the results obtained with this.

The appendix presents a method for evaluating the selection of the step of discreteness and the necessary number of tests when simulating incoming flows and intervals of duty of the instruments in queueing systems.

Since the machines of the Unified System of Electronic Computers are compatible with the machines of the 360/system, on one of which the authors have carried out digital simulation, the experiment presented in the book of this simulation may prove to be quite useful in setting up analogous work on machines of the Unified Series of Electronic Computer series.

The authors consider it their pleasant duty to thank N. P. Buslenko, corresponding member of the USSR Academy of Sciences, and B. A. Shchukin, candidate of technical sciences, for the valuable comments that they expressed during the reading of the manuscript for the book.

The authors do not feel that the work on the material set forth in this book is completed, and therefore they will be grateful to readers who send their comments and wishes to the address: 113114, Moscow, M-114, Shlyuzovaya Embankment, 10, Izdatel'stvo Energiya.

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PUBLICATIONS

UDC 658.012.011.56:681.3

RECORDING AND GATHERING PRIMARY INFORMATION FOR ASUP'S

Moscow REGISTRATSIYA I SBOR PERVICHNOY INFORMATSII V ASUP in Russian 1978 signed to press 2 Feb 78 pp 2-4, 88

[Annotation, foreword and table of contents of book by A. P. Ivanov and S. B. Abramov, Energiya, 11,000 copies, 88 pages]

[Annotation]

[Text] This book discusses a number of methodological problems of substantiating the type and calculating the amount of peripheral equipment in ASUP and the problem of the compatible operation of the EVM [Electronic computer], and gives a survey and brief technical description of the domestic equipment for recording and gathering the primary information, as well as the tendencies in their development and examples of usage.

The book is designed for engineers and technicians engaged in working out the software for ASUP, workers at computation centers and also students at VUZ's with the corresponding specialties.

Foreword

The rise in productivity of the EVM increases the gap between the potentials of the machines and the personnel engaged in preparing the information and problems to be solved on the EVM. These preparatory stages are characterized by a considerable proportion of manual, low-productive labor, and hold back efficient use of the EVM. For example, for one hour of work on an EVM with average productivity, 70-100 hours of manual labor are required to prepare the machine information carriers, and for more highly productive EVM, one minute of the operational process requires one day of preparatory work.

Correlation of the time for preparing data and the time for processing them on an EVM can today no longer be ensured through a simple increase in the number of corresponding personnel at the computation center. There must be maximum automation of the process of preparing and feeding the information to the EVM. In accordance with these principles, data processing in an ASU requires the use of a ramified network of peripheral devices, which ensure the recording and gathering of the primary information on the state and dynamics of the production processes with the necessary speed, accuracy and reliability. Consequently, the efficiency of using the EVM is closely related to organizing the work of the set of hardware of the ASU as a whole, important units of which are the external devices of the EVM (VnU) and the peripheral equipment of the ASU (PrfO).

On the one hand, the composition and parts schedule of the VnU and PrfO, which determine the configuration of the computation system, depend on the EVM, and on the other--the selected EVM has a decisive influence on the substantiation and composition of the set of hardware of the ASUP and the organization of the computation process as a whole. Because of this, the substantiated selection of the PrfO is a fully independent and no less important stage than the selection of the EVM. To this it remains to be added that the proportion of the cost of the PrfO in modern ASUP is quite sizeable and constitutes on the average 30-40 percent of the capital expenditures to set up the systems.

There is a considerable expansion of the role of PrfO in reorganizing the industrial process for processing the data, based on the concepts of a data bank. One of the basic concepts is the equipment and program division of the functions of recording and gathering the initial data, on the one hand, and the conversion of the ordered arrays when solving specific problems, on the other. This essentially means that the input of primary information ultimately joins into the aggregate of organized arrays (base of the data) and the promptness and reliability of the calculations depend to a considerable extent on the initial stages of processing--recording and gathering the primary information. In accordance with these principles, in the modern systems the stage of punching the data is gradually eliminated as very labor-intensive and characterized by a large number of errors, and preparing the machine carriers and filling out the primary documents coincides in time and with respect to equipment.

Among the means of recording and gathering information for the ASUP are included devices, units and systems which make it possible to gather the primary data, prepare them for input to the EVM and monitor the correctness of the input at the same time that the forms of the primary documents are filled out. In this case, recording means recording the data onto the machine carrier and (or) the document, gathering--obtaining the data through some device from a number of sources, and transmission--supplying the carriers (by some specific method, including the use of communication lines) for processing at the computation center.

This book is devoted to methodological questions of selecting the type and calculating the amount of peripheral equipment for an ASU for enterprises with a series type of production. Problems of substantiating the external devices of the EVM are paid much less attention. This is because the latter are usually solved in the substantiation of the configuration of the computation systems and have been quite fully dealt with in domestic literature.

The basic purpose of the book is to serve as a practical and reference handbook in solving a number of problems of ASU hardware. With a view to this, there is a detailed description of the characteristics of machine information carriers, standards and codes for entering the data on the carriers, since the data carrier is the connecting link between the devices for recording the data and the devices for processing them. The book devotes considerable attention to problems of using modern peripheral equipment in ASU. For this purpose, brief technical-operational descriptions are given of the domestic PrfO and external devices of the unified series EVM, which expand the potentials of the EVM in data processing systems. Particular attention is paid to the compatible, coordinated work of individual units and basic models of domestic EVM. The book is illustrated with methods of using the peripheral equipment in ASUP (efficient count of the production and counting of materials at the warehouse).

Problems of the reliability of the initial information are of primary importance in the practical work of ASU. The limited volume of the book made it impossible for the authors to deal with this problem fully and, furthermore, there are sufficient works on this subject in domestic literature. For these reasons the authors restricted themselves to discussing only the methods and means of monitoring that are used in domestic PrfO.

Chapters 1 and 2 of the book were written by A. P. Ivanov (foreword, sections 1, 5, 7), S. B. Abramov (sections 2-4) and the remaining sections--jointly. Chapter 3 was written by S. B. Abramov with the assistance of Ye. A. Khrutskiy.

The authors consider it their pleasant duty to express deep gratitude to V. A. Gorbatov, doctor of technical sciences, and V. F. Dem'yanov, candidate of technical sciences, for discussing the contents, becoming thoroughly familiar with and working on the manuscript, which contributed to a considerable improvement in it. The authors are also grateful to Yu, M. Repyev, candidate of technical sciences, for his constructive comments and wishes, during the reviewing of the manuscript.

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SEMINAR ON STATISTICAL HYDROACOUSTICS

Novosibirsk TRUDY VOS'MOY VSESOYUZNOY SHKOLY-SEMINARA PO STATISTICHESKOY GIDROAKUSTIKE (Proceedings of the Eighth All-Union School-Seminar on Statistical Hydroacoustics) in Russian 1977 signed to press 14 Dec 77 pp 3, 192-194

/Annotation and table of contents from book edited by N. G. Zagoruyko, V. V. Ol'shevskiy, S. V. Pasechnyy, Institute of Mathematics of the Siberian Department of the USSR Academy of Sciences, 400 copies, 194 pages/

/Text/ The collection contains the materials of the Eighth All-Union School-Seminar on Statistical Hydroacoustics, which was organized by the Council for Hydrophysics attached to the Presidium of the USSR Academy of Sciences, the Institute of Acoustics of the USSR Academy of Sciences, the Taganrog Institute of Radio Engineering, the Interoblast Board of the Scientific and Technical Society imeni Academician A. N. Krylov, the Institute of Mathematics of the Siberian Department of the USSR Academy of Sciences and the Kiev Polytechnic Institute.

The classes of the school-seminar were held at the base of the Taganrog Institute of Radio Engineering in the city of Taganrog from 8 through 14 September 1976.

The theme of the collection includes questions of the study of the characteristics of the aqueous medium and its boundaries, direct hydroacoustic signals, reverberation and echo signals; questions of statistical measurements and modeling; questions of signal processing against a background of interference.

The materials of the proceedings are of interest for scientists and specialist in the area of hydrophysical research and data processing, graduate students, engineers and students of the upper grades.

Editorial collegium: V. V. Ol'shevskiy (editor in chief), N. G. Gatkin, N. G. Zagoruyko, S. V. Pasechnyy, L. Ya. Taradanov (academic secretary).

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PUBLICATIONS

UDC 539.125.5

INSTITUTE OF PHYSICS BOOK ON PULSED NEUTRON RESEARCH

Moscow TRUDY ORDENA LENINA FIZICHESKOGO INSTITUTA IMENI P.N. LEBEDEVA AKADEMII NAUK SSSR: IMPUL'SNYYE NEYTRONNYYE ISSLEDOVANIYA ("Pulsed Neutron Research") in Russian Vol 94, 1977 pp 1-2, 102

[Annotation and Table of Contents from the book edited by academician N. G. Basov, Izdatel'stvo "Nauka", 1,150 copies, 104 pages]

[Text] In the experimental and theoretical papers presented in this collection, the processes studied are primarily those in which a "neutron gas", located either in a vacuum or in matter, manifests the collective properties of a statistical set of Fermi particles.

For a number of substances, changes in the neutron physics constants are studied for the case of phase transitions of the first kind.

The collection is intended for physicists engaged in neutron research of solids, studying the properties of ultracold neutrons and working on the design of nuclear and thermonuclear reactors.

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PUBLICATIONS

CONSTRUCTION MACHINERY AUTOMATED CONTROL SYSTEMS

Leningrad AVTOMATIZIROVANNYYE SISTEMY UPRAVLENIYA STROITEL'NYMI MASHINAMI (Construction Machinery Automated Control Systems) in Russian 1977 signed to press 26 Oct 1977 pp 2, 223-224

[Annotation and Table of Contents from book by A. A. Yerofeyev, Mashinostroyeniye, 5,000 copies, 224 pages]

[Text] This book is the first to synthesize data on development and practical adoption of automatic and automated control systems (ASU) for the production processes of the principal types of construction machinery. The author examines an aggregate of questions pertaining to control of construction machinery continuous-discrete production processes. The author describes the principles of design and features of construction machinery ASU structures; the book contains diagrams and models of automatic systems, their static and dynamic characteristics, and presents methods and theoretical principles for designing these systems.

This book is intended for engineers and technicians engaged in the development, design and operation of automatic and automated control systems. It can also be utilized by students at higher educational institutions in the corresponding areas of specialization.

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VOLUME DEVOTED TO WORK OF MATHEMATICIAN LYAPUNOV

Moscow PROBLEMY KIBERNETIKI in Russian 1977 No 32, 17 Oct 77 p 7

[Table of contents of book "Problemy Kibernetiki" (Problems of Cybernetics) edited by S. V. Yablonskiy, "Nauka" Publishers, 3,700 copies, 248 pages]

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PUBLICATIONS

NEW BOOK REVIEWS PROCESS OF ASU DESIGN, EVALUATION

Moscow TEORETICHESKIYE OSNOVY POSTROYENIYA AVTOMATIZIROVANNYKH SISTEM UPRAVLENIYA (RAZRABOTKA TEKHNICHESKOGO PROYEKTA) in Russian 1978 signed to press 6 Jan 78 pp 2, 293-294

[Annotation and table of contents of book "Teoreticheskiye Osnovy Postroyeniya Avtomatizirovannykh Sistem Upravleniya (Razrabotka Tekhnicheskogo Proyekta)" [Theoretical Foundations of Constructing Automated Control Systems (Development of the Contract Design)] by A. A. Voronov, G. A. Kondrat'yev, and Yu. V. Chistyakov, Izdatel'stvo Nauka, 4,000 copies, 295 pages]

[Text] Annotation

This book is devoted to a systematic presentation of the questions of developing the contract design of an automated control system (ASU).

It considers formalized description of statements and solution algorithms. Questions of the economic substantiation for selection of design decisions in various states of preparation of the contract design are worked out. The book offers recommendations on designing the information support, software, and hardware and on modifying the structure of the system to insure the maximum guaranteed expectation of economic efficiency achievable under conditions of natural limitations on the resources of the developer organization.

The book is intended for a broad range of specialists interested in the issues of system design, ASU developers in various national economic sectors, and students in the corresponding specializations at higher educational institutions. There are 13 illustrations, 282 bibliographic entries, and 31 tables.

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PUBLICATIONS

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GAUSSIAN LIGHT BEAMS

Minsk GAUSSOVY PUCHKI SVETA in Russian 1977 signed to press 20 Jan 77, pp 1-4, 141-142

[Annotation, table of contents and introduction from the book by A.M. Goncharenko, Nauka i Tekhnika Publishers, 1,800 copies, 144 pages]

[Text] Gaussian light beams are good descriptions of actual narrow light beams, in particular, laser radiation, the resonant modes of open resonators and optical light guides. The properties of Gaussian beams in isotropic and anisotropic media are treated in the monograph. Both circular and elliptical beams are studied. The first take the form of resonant modes of resonators with spherical reflectors having an isotropic filler, while the second take the form of the modes of astigmatic laser resonators or resonators filled with an anisotropic medium, as well as astigmatic light guides. The propagation of light beams in inhomogeneous, lenticular media is studied, taking into account amplification and absorption. The influence of the anisotropy of the dielectric permittivity of the medium on the spatial form, phase surface and divergence of light beams is ascertained.

The monograph is intended for students in the senior courses of physics departments, teachers, engineers and scientific associates working in the field of optical and quantum electronics.

1 Table; 29 illustrations; 64 bibliographic citations.

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Introduction

Plane electromagnetic waves as the simplest form of waves are usually employed in the initial analysis or description of the majority of optical phenomena. The concept of a plane wave includes spatial and timewise invariance of the shape of the phase (planar) surface and amplitude. However, actual light beams are always limited, primarily in transverse directions. The diffraction of such a beam leads to a constant change in the space of the amplitude and to distortion of the phase surface. These specific features of a beam must be taken into account when describing the propagation of narrow light beams, for example, the radiation of lasers (OKG).

The coherent radiation which is generated by lasers and masers, takes the form of narrow beams, the transverse dimensions of which, however, are many times greater than the wavelength. For this reason, the diffraction divergence of such beams is comparatively small, while their amplitude varies slowly with the longitudinal coordinate. Such light beams are well described by gaussian beams, in which the amplitude in the transverse plane varies in accordance with a Gaussian-Hermitian law, while the phase surface is distorted in step with the propagation of the beam. It has now been demonstrated and generally accepted that gaussian beams most simply and completely describe the properties of laser light beams and the resonant modes of the open resonators of lasers. Admittedly, gaussian beams are also an approximation, but are a sufficiently good one.

The area of applications of laser beams is extremely large at the present time, and extends from purely scientific fields such as nonlinear and integral optics to the machine construction inductry. In this case, it is necessary to consider the specific features of the propagation and the properties of laser beams in the most diverse media: transparent and opaque, homogeneous and inhomogeneous, isotropic and anisotropic, etc. In this regard, it is desirable to make a detailed study of the properties of gaussian (laser) light beams in the most diverse media. This is precisely the goal which this monograph pursues. The methods of wave optics are employed in it, although one can also use geometric optics (see, for example, [1]) to describe gaussian beams. The results of the work of Soviet and foreign authors, as well as the research of the author and coworkers, performed in the last 10 years, are reflected in the monograph.

The propagation of gaussian beams in nonlinear and gyrotropic media, as well as the reflection, refraction and diffraction of gaussian beams are not treated in the book. It seems to us that these questions are as yet inadequately worked out, although they are of interest in quantum electronics and integral optics.

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PRINCIPLES OF CONSTRUCTION OF AUTOMATED CONTROL SYSTEMS

Moscow OSNOVY POSTROYENIYA AVTOMATIZIROVANNYKH SISTEM UPRAVLENIYA in Russian 1977 signed to press 16 Sep 77 pp 2, 301-302

[Annotation and table of contents from the book by V. I. Kostyuk, Yu. P. Zaychenko, N. G. Zaytsev, N. I, Kirilyuk and R. V. Lebedinskiy; edited by V. I. Kostyuk, Izdatel'stvo Sovetskoye Radio, 304 pp, 37,000 copies]

[Text] Annotation

The textbook gives a complex concept of basic questions in the planning and construction of an automated control system [ASU]: systems analysis of ASU, the principles of construction servicing subsystems of ASU, operations control, material and equipment supply, technical-economic planning, etc. Also examined are questions of the construction of complex ASU hardware and software, the organization of designing, and also ergonomic and engineering-psychological problems of ASU.

The textbook is intended for students and scientific and technical workers engaged in the designing and introduction of ASU.

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